Water Quality Sampling Report

U.S. Army Corps of Engineers
Omaha District

Additional Sediment/Soil Sampling Conducted at the Little Sioux Bend Shallow Water Habitat Project Site during October 2013

November 2013

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Prepared by:

Water Quality Unit
Water Control and Water Quality Section
Hydrologic Engineering Branch
Engineering Division
Omaha District
U.S. Army Corps of Engineers

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (USACE) is proposing a project to construct shallow-water habitat (SWH) along the Little Sioux Bend of the Missouri River between RM666 and RM669. The construction of SWH will enhance the aquatic habitat of the Missouri River and benefit the endangered pallid sturgeon (*Scaphirhynchus albus*) population. Although on the Nebraska side of the Missouri River, the project area is located in Harrison County, Iowa and Burt County, Nebraska and will basically run down the old river channel that is the legal boundary between the States of Iowa and Nebraska. The USACE is proposing to use hydraulic dredging to excavate sediment/soil from the old river channel and discharge the dredge spoil to the Missouri River adjacent to the proposed project area. Section 404 of the Federal Clean Water Act (CWA) requires that a §404 permit be appropriately obtained prior to the discharge of any dredge or fill material into waters of the United States. Under §401 of the Federal CWA an applicant for a federal license or permit (i.e. §404 permit) must obtain a certification that the discharge and activity is consistent with appropriate State or Tribal water quality regulations. Regarding the Little Sioux project, a §401 water quality certification has been requested from the Iowa Department of Natural Resources (IDNR) and Nebraska Department of Environmental Quality (NDEQ) regarding compliance with State water quality standards and implementation plans. The Water Quality Sampling Report and Factual Determinations, "Results of Sediment Sampling and Elutriate Testing at the Proposed Little Sioux Bend Shallow Water Habitat Project Site" (USACE, April 2013) was previously prepared to support Section 404 permitting and State §401certification considerations at the proposed Little Sioux project. Subsequent to that report and conducted sediment sampling, the State of Iowa expressed concerns that the proposed hydraulic dredging to construct SWH at the Little Sioux project may lead to unacceptable nutrient loading to the Missouri River. An expressed concern was that the conducted sediment/soil sampling was not extensive enough (both spatially and depth of sampling) to allow nutrient loading questions to be adequately assessed. Additional sediment/soil sampling was conducted by the USACE at the proposed Little Sioux project site to further address the concerns expressed by the IDNR. The collected sediment/soil samples were analyzed for particle size, total phosphorus, total Kjeldahl nitrogen, and nitrate-nitrite nitrogen.

Thirty-seven sediment/soil samples were collected among eight sampling locations at the proposed Little Sioux project site on 16 and 21-October-2013. Sediment/soil core samples were collected and composited every 2 feet to a depth of 10 feet where possible. Sampling depth was limited to 8 and 6 feet, at two of the sites due to the collapse of the bore hole in saturated soils below the water table – resulting in the collection of the 37 additional sediment/soil samples. The composition of the 37 collected sediment/soil samples ranged from 42.4 to 91.1 percent sand (8.9 to 57.6 percent fines) and averaged 73.6 percent sand (26.4 percent fines). Nutrient levels measured in the 37 collected sediment/soil samples ranged from 271 to 624 mg/kg (430 mg/kg average) total phosphorus, 52 to 1,070 mg/kg (282 mg/kg average) total Kjeldahl nitrogen, and non-detectable to 2.6 mg/kg (non-detectable 75th percentile) nitrate-nitrite nitrogen.

The measured nutrient levels were statistically-tested for significant differences ($\alpha = 0.05$) between sampling location and depth. Regarding the measured total phosphorus levels, there was a significant difference among sampling sites, but no significant difference with sample depth. Regarding measured total Kjeldahl nitrogen levels, there was a significant difference among sampling sites, but no significant difference with sample depth. Regarding nitrate-nitrite nitrogen, there was no significant difference among sampling sites and with sampled depth. It is noted nitrate-nitrite nitrogen was nearly significantly different with depth.

The total tonnage of nutrients likely present in the sediment/soil proposed for excavation at the Little Sioux project area was estimated from the measured sediment/soil nutrient levels and the design excavation volumes. It is estimated that the total 430,000 CY of sediment/soil to be excavated at the proposed Little Sioux project area contains 236 tons of total phosphorus, 145 tons of total Kjeldahl nitrogen, and less than 1 ton of nitrate-nitrite nitrogen. The estimated total nutrient tonnage was appropriately allocated, based on design excavation volumes, to the three depth layers (i.e. 0-3 feet, 3-6 feet, and > 6 feet) that have been proposed by the IDNR for alternative disposal. The total phosphorus tonnage estimated to be in the three layers is 71.3 tons (0-3 feet), 57.4 tons (3-6 feet), and 107.7 tons (>6 feet).

The National Research Council of the National Academies published the report, "Missouri River Planning – Recognizing and Incorporating Sediment Management" which assessed nutrient loadings to the Missouri River and Gulf of Mexico (NRC, 2011). The report concluded that potential nitrogen loading from hydraulic dredging to construct SWH along the Missouri River was likely not a concern, but total phosphorus loadings could be a concern regarding Gulf of Mexico hypoxia. Currently, the total phosphorus load to the Gulf of Mexico is estimated to be 154,300 metric tons per year, with the contribution of the Missouri River to this total load estimated to be between 16.8% and 20% (NRC, 2011). Assuming the proposed SWH construction at the Little Sioux project area would be completed within one year, the total phosphorus tonnage in the proposed 430,000 CY to be excavated represents 0.76% of the current yearly total phosphorus loading in the Missouri River, and 0.14% of the annual total phosphorus load delivered to the Gulf of Mexico. These percentages are upper bound estimates, as sediment deposition processes in the Missouri and Mississippi River channels would reduce total phosphorus loads delivered to the Gulf, and actual downstream deliveries would be significantly less than these values.

Total phosphorus in Iowa soils tends to be higher in the surface horizon, decreases to a minimum and then increases with depth within members of the biosequence (Fenton, 1999). The general trend of the distribution is similar whether the parent material is loess or glacial till (Fenton 1999). The total phosphorus levels measured in the collected sediment/soil samples at the proposed Little Sioux project area are within the range of expected values based on soils and land use present at the project site, and exhibit a similar relationship with depth as indicated for Iowa soils by Fenton, 1999.

1 BACKGROUND INFORMATION

1.1 Project Description

A project is being proposed to create shallow-water habitat (SWH) along the Missouri River in Harrison County, Iowa and Burt County, Nebraska. The U.S. Army Corps of Engineers (USACE) is constructing SWH along the lower Missouri River downstream of Gavins Point Dam to mitigate aquatic habitat lost from past bank stabilization and channelization. Increasing SWH will enhance the endangered pallid sturgeon (*Scaphirhynchus albus*) population along the lower Missouri River. The District is referring to the proposed project as the Little Sioux project. Hydraulic dredging is being proposed to excavate sediment/soil from an old chute area of the Missouri River to create SWH. The material to be dredged is believed to be primarily sands and silts with some clays. It is proposed that the dredge spoil be discharged to the Missouri River adjacent to the proposed project area.

1.2 Project Location

The project area is located in Harrison County, Iowa and Burt County, Nebraska along the Little Sioux Bend of the Missouri River between RM666 and RM669. The project area is on the Nebraska side of Missouri River and will basically run down the old river channel that is the legal boundary between the States of Iowa and Nebraska (Figure 1). Figure 2 shows the proposed area for excavation to create SWH at the Little Sioux project area.

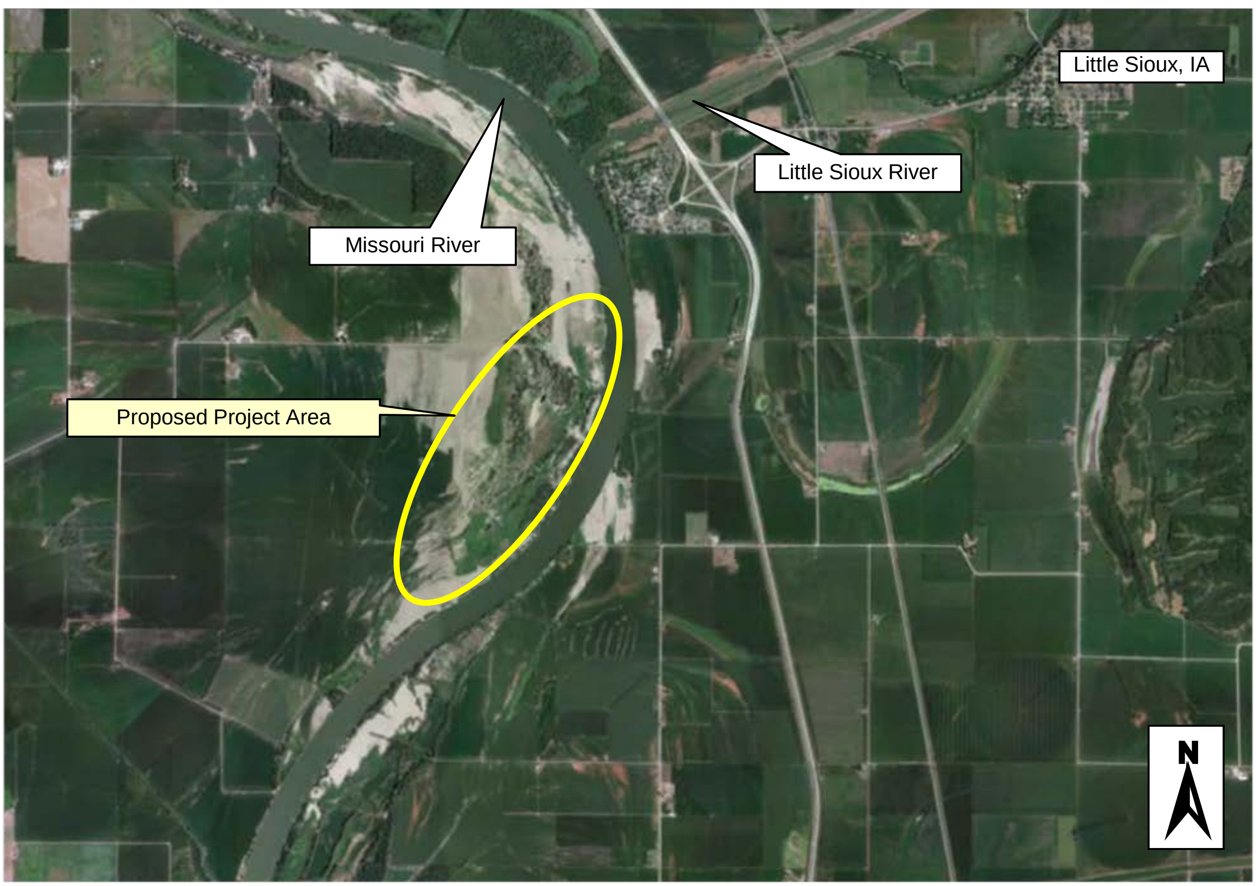


Figure 1. Location of proposed Little Sioux project site along the Missouri River west of Little Sioux, Iowa. *(Imagery Date: 18-July-2012, Google Earth)*

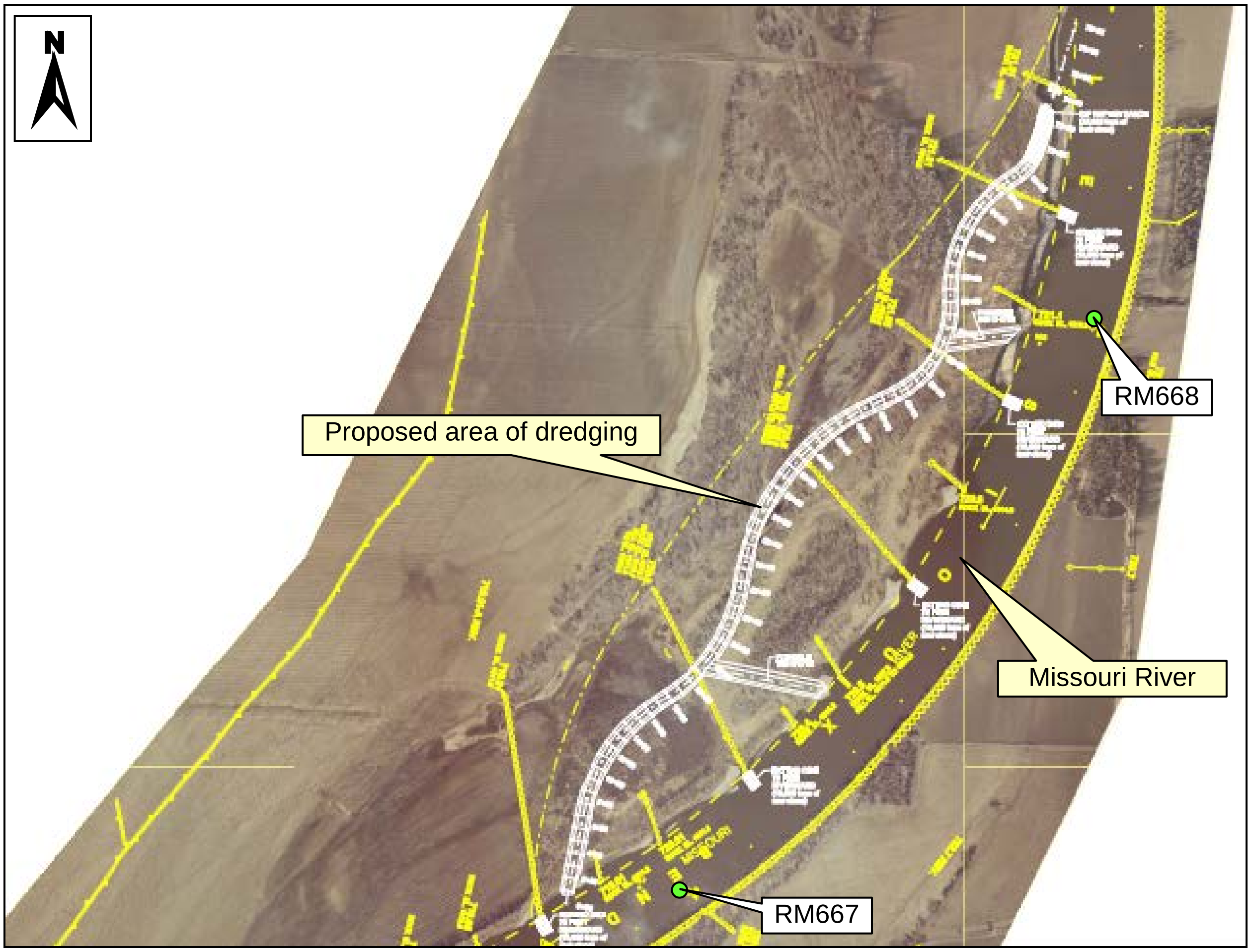


Figure 2. Proposed excavation to create shallow-water habitat at the Little Sioux project area.

1.3 <u>Section 404 Permitting Requirements – 404(b)(1) Guidelines</u>

Section 404 of the Federal Clean Water Act (CWA) requires that a §404 permit be appropriately obtained prior to the discharge of any dredge or fill material into waters of the United States. The issuance of §404 permits is pursuant to the Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material (404(b)(1) Guidelines) [40 CFR Ch. I (7-1-10 Edition)]. Fundamental to the 404(b)(1) Guidelines is the precept that dredged or fill material should not be discharged into the aquatic ecosystem, unless it can be demonstrated that such a discharge will not have an unacceptable adverse impact either individually or in combination with known and/or probable impacts of other activities affecting the ecosystems of concern. No discharge of dredged or fill material is permitted: 1) if it will cause or contribute, after consideration of disposal site dilution and dispersion, to violations of any applicable State water quality standard; 2) if it will cause or contribute to significant degradation of the waters of the United States; or 3) unless appropriate and practicable steps have been taken which will minimize potential adverse impacts of the discharge on the aquatic system.

Compliance with the 404(b)(1) Guidelines is based, in part , on "Factual Determinations" of the potential impact of the proposed dredge and fill on the aquatic environment. The §404 permitting authority is required to determine in writing the potential short-term or long-term effects of a proposed discharge of dredged or fill material on the physical, chemical, and biological components of the aquatic

environment. These Factual Determinations are used in making findings of compliance or non-compliance with the restrictions on discharge. The 404(b)(1) Guidelines at §230.11 identify the following eight Factual Determinations that are to be made on the effects of each proposed discharge of dredge and fill material:

1) Physical substrate determinations.
2) Water circulation, fluctuation, and salinity determinations.
3) Suspended particulate/turbidity determinations.
4) Contaminant determinations.
5) Aquatic ecosystem and organism determinations.
6) Proposed disposal site determinations.
7) Determination of cumulative effects on the aquatic ecosystem.
8) Determination of secondary effects on the aquatic ecosystem.

The intent of this report is to provide additional information to support Factual Determinations of the potential water quality impacts of hydraulic dredging discharge at the proposed Little Sioux project on the Missouri River. As defined in the Federal CWA and USACE Regulation No. 1110-2-8154, water quality is defined as the physical, chemical, and biological characteristics of water.

1.4 Section 401 Water Quality Certification

Under §401 of the Federal CWA an applicant for a federal license or permit (i.e. §404 permit) must obtain a certification that the discharge and activity is consistent with State or Tribal effluent limitations (CWA §301), water quality related effluent limitations (CWA §302), water quality standards and implementation plans (CWA §303), national standards of performance (§306), toxic and pretreatment effluent standards (CWA §307) and "any other appropriate requirement of State or Tribal law set forth in such certification." Regarding the Little Sioux project, a §401 water quality certification will be requested from the Iowa Department of Natural Resources (IDNR) and Nebraska Department of Environmental Quality (NDEQ) regarding compliance with State water quality standards and implementation plans. It is noted that the State of Iowa has recently released the "Iowa Nutrient Reduction Strategy – A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico".

1.5 Reporting of Water Quality Considerations and Factual Determinations

The Water Quality Sampling Report and Factual Determinations, "Results of Sediment Sampling and Elutriate Testing at the Proposed Little Sioux Bend Shallow Water Habitat Project Site" (USACE, April 2013) was previously prepared to support Section 404 permitting and State §401certification considerations at the proposed Little Sioux project. Subsequent to that report, and the conducted sediment sampling at the proposed Little Sioux project site, the State of Iowa expressed concerns that the proposed hydraulic dredging to construct SWH at the Little Sioux project may lead to unacceptable nutrient loading to the Missouri River. An expressed concern was that the conducted sediment/soil sampling was not extensive enough (both spatially and depth of sampling) to allow nutrient loading questions to be adequately assessed. The information provided in this report is meant to further address this concern.

2 SAMPLING AND ANALYSIS METHODS

Additional sediment/soil samples, representative of the areas to be excavated for SWH construction at the proposed Little Sioux project site, were collected and analyzed.

2.1 Sampling and Analysis Plan

A Sampling and Analysis Plan (SAP) addendum to the previously implemented SAP was developed to collect and analyze additional sediment/soil samples at the proposed Little Sioux project site. The SAP addendum was developed to increase the available information on the spatial and depth variability of nutrient conditions of the sediment/soil in the areas proposed for excavation at the Little Sioux project site. The SAP addendum was implemented as written, with one modification, and is included as Attachment 1. The one modification was that percent solids was also analyzed and reported for the collected sediment/soil samples. The parameters that were analyzed in the laboratory for the collected sediment/soil samples are listed in Table 1.

Table 1. Parameters analyzed in the laboratory for the collected sediment/soil samples.

Parameter	Method	Detection Limit
PHYSICAL AND AGGREGATE PROPERTIES		
Particle Size	Sieve (Minimum Sieve #200)	0.001 mm
Percent Solids	SM 2540G	0.01%
NUTRIENTS		
Nitrogen, Kjeldahl Total as N	EPA 351.3	0.2 mg/kg
Nitrogen, Nitrate/Nitrite Total as N	EPA 353.2	0.02 mg/kg
Phosphorus, Total	SM 4500PF	0.02 mg/kg

2.2 Collection of Sediment/Soil Samples

Thirty-seven sediment/soil samples were collected among eight sampling locations at the proposed Little Sioux project site on 16 and 21-October-2013. The eight sampling locations (i.e. sites LS-D1, LS-D2, LS-D3, LS-D4, LS-D5, LS-D6, LS-D7, and LS-D8) where the sediment/soil samples were collected are shown on Figures 3 through 5 and described in Tables 2 and 3. The sediment/soil samples at each of the eight sites were collected with a gas-powered auger equipped with a 3¼ -inch diameter stainless steel coring bit. Core samples were collected and composited every 2 feet to a depth of 10 feet where possible. Sampling depth was limited to 8 and 6 feet, respectively, at sites LS-D2 and LS-D5 due to the collapse of the bore hole in saturated soils below the water table.

3 RESULTS

3.1 Physical and Aggregate Properties

Tables 4 through 12 provide a summary of the particle size and percent solids conditions determined for the 37 collected sediment/soil samples at sites LS-D1, LS-D2, LS-D3, LS-D4, LS-D5, LS-D6, LS-D7, and LS-D8. Figures 6 through 13 plot the same information. Attachment 2 provides the Particle Size Distribution Reports prepared by Midwest Laboratories for the collected sediment/soil samples.

3.2 Nutrients

Tables 13 through 20 provide a summary of the nutrient conditions determined for the 37 collected sediment/soil samples at sites LS-D1, LS-D2, LS-D3, LS-D4, LS-D5, LS-D6, LS-D7, and LS-D8. Figures 14 through 21 plot the same information. Attachment 3 provides the nutrient data as analyzed by Midwest Laboratories (Omaha, Nebraska) for the collected sediment/soil samples.

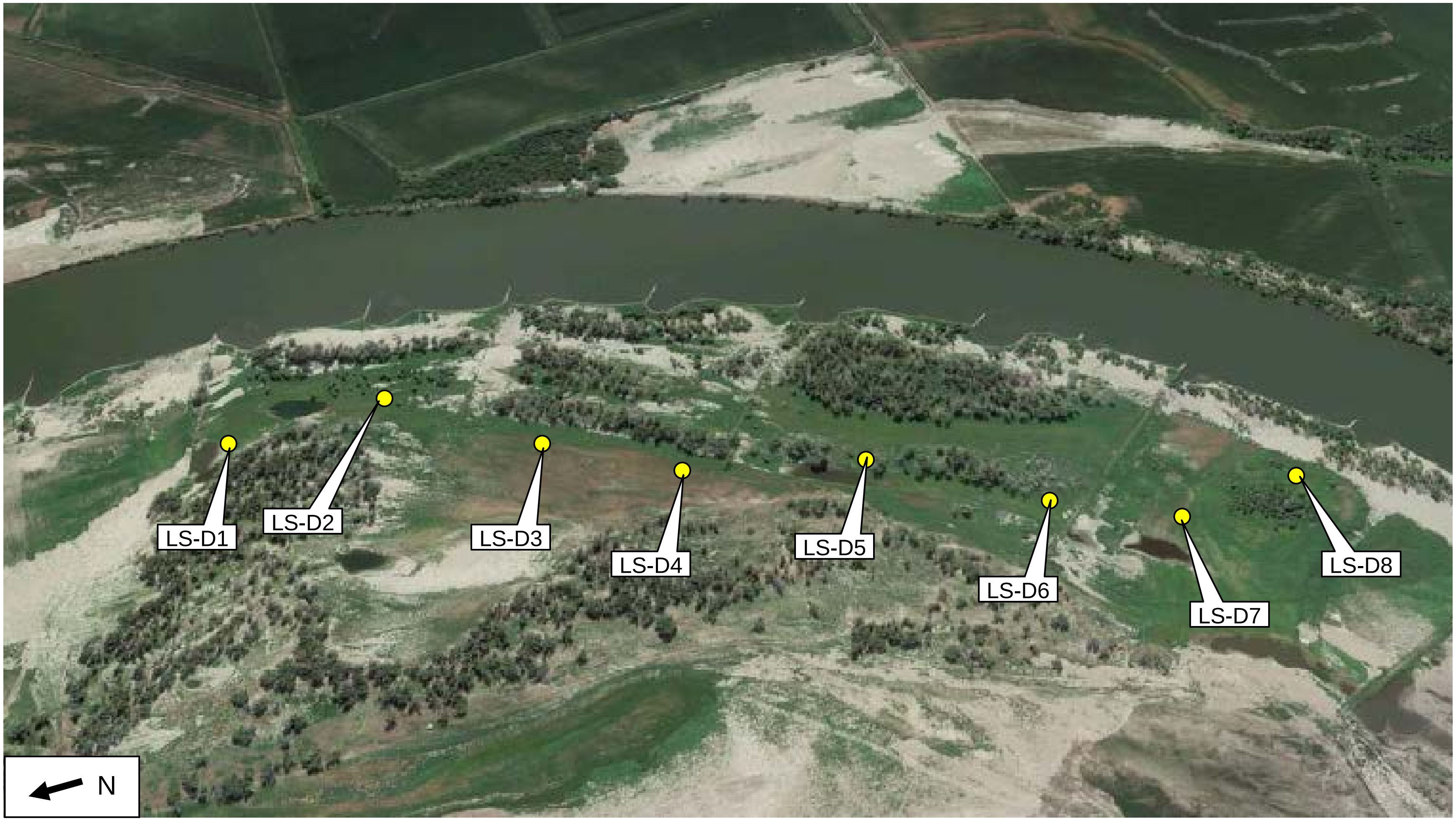


Figure 3. Location of the eight sites where soil/sediment samples were collected for additional analyses at the Lower Sioux Bend SWH project site on 16 and 21 October 2013. *(Imagery Date: 18-Jul-2012)*

Figure 4. Approximate locations of sites LS-D1, LS-D2, LS-D3, and LS-D4 where additional soil/sediment samples were collected at the Little Sioux Bend SWH project site on 21-October-2013. *(Imagery Date: Nov-2013)*

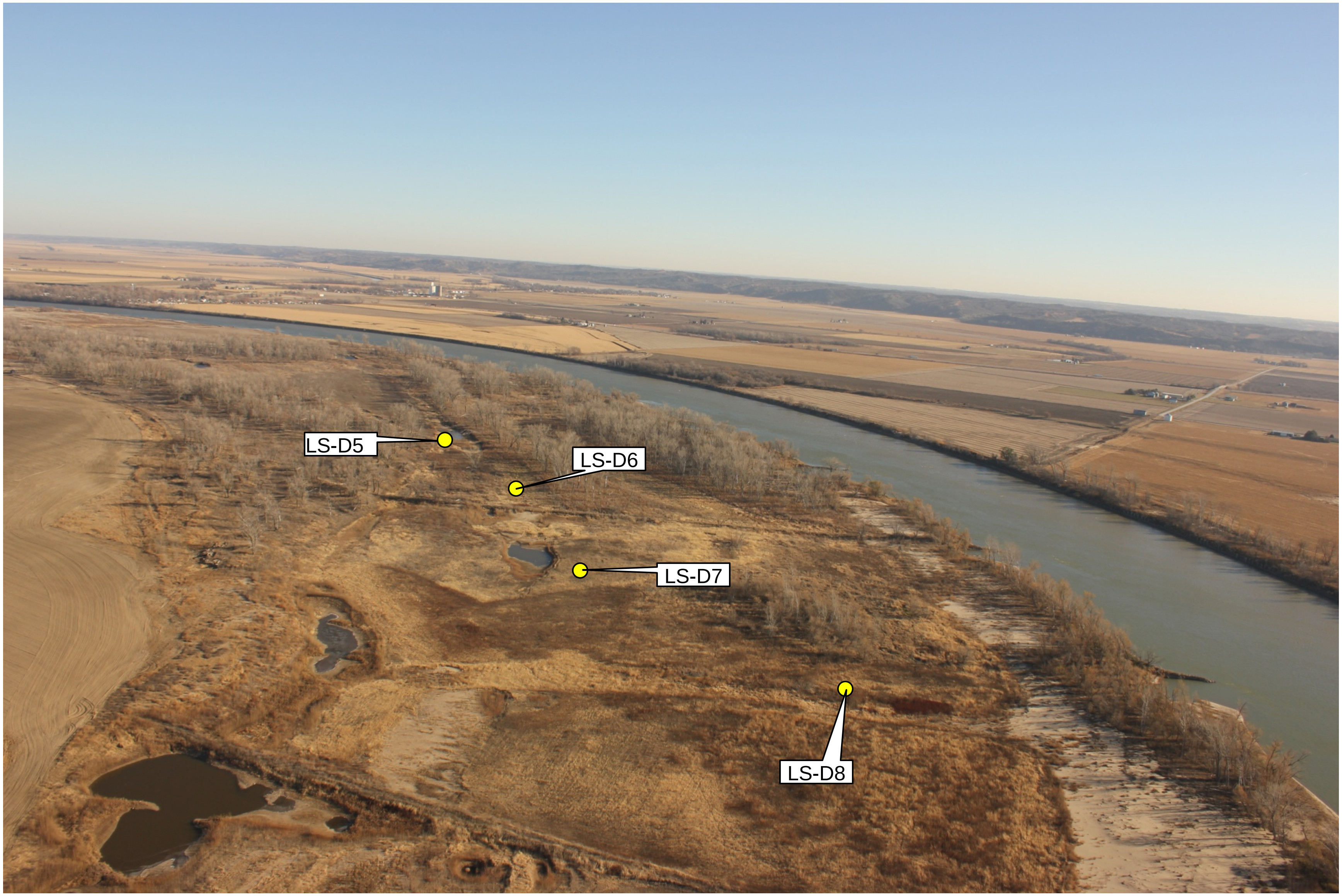


Figure 5. Approximate locations of sites LS-D5, LS-D6, LS-D7, and LS-D8 where additional soil/sediment samples were collected at the Little Sioux Bend SWH project site on 16 and 21-October-2013. *(Imagery Date: Nov-2013)*

Table 2. Additional sediment/soil samples collected at the proposed Little Sioux project site.

Sampling Site	Sample ID	Sampled Depth	Date, Time	Sample Type
LS-D1	LS-D1A	0 – 2 feet	21-Oct-13, 14:30	Composite Core
	LS-D1B	2 – 4 feet	21-Oct-13, 14:30	Composite Core
	LS-D1C	4 – 6 feet	21-Oct-13, 14:30	Composite Core
	LS-D1D	6 – 8 feet	21-Oct-13, 14:30	Composite Core
	LS-D1E	8 – 10 feet	21-Oct-13, 14:30	Composite Core
LS-D2	LS-D2A	0 – 2 feet	21-Oct-13, 13:10	Composite Core
	LS-D2B	2 – 4 feet	21-Oct-13, 13:10	Composite Core
	LS-D2C	4 – 6 feet	21-Oct-13, 13:10	Composite Core
	LS-D2D	6 – 8 feet	21-Oct-13, 13:10	Composite Core
LS-D3	LS-D3A	0 – 2 feet	21-Oct-13, 12:30	Composite Core
	LS-D3B	2 – 4 feet	21-Oct-13, 12:30	Composite Core
	LS-D3C	4 – 6 feet	21-Oct-13, 12:30	Composite Core
	LS-D3D	6 – 8 feet	21-Oct-13, 12:30	Composite Core
	LS-D3E	8 – 10 feet	21-Oct-13, 12:30	Composite Core
LS-D4	LS-D4A	0 – 2 feet	21-Oct-13, 11:50	Composite Core
	LS-D4B	2 – 4 feet	21-Oct-13, 11:50	Composite Core
	LS-D4C	4 – 6 feet	21-Oct-13, 11:50	Composite Core
	LS-D4D	6 – 8 feet	21-Oct-13, 11:50	Composite Core
	LS-D4E	8 – 10 feet	21-Oct-13, 11:50	Composite Core
LS-D5	LS-D5A	0 – 2 feet	21-Oct-13, 10:20	Composite Core
	LS-D5B	2 – 4 feet	21-Oct-13, 10:20	Composite Core
	LS-D5C	4 – 6 feet	21-Oct-13, 10:20	Composite Core
LS-D6	LS-D6A	0 – 2 feet	21-Oct-13, 9:30	Composite Core
	LS-D6B	2 – 4 feet	21-Oct-13, 9:30	Composite Core
	LS-D6C	4 – 6 feet	21-Oct-13, 9:30	Composite Core
	LS-D6D	6 – 8 feet	21-Oct-13, 9:30	Composite Core
	LS-D6E	8 – 10 feet	21-Oct-13, 9:30	Composite Core
LS-D7	LS-D7A	0 – 2 feet	16-Oct-13, 15:00	Composite Core
	LS-D7B	2 – 4 feet	16-Oct-13, 15:00	Composite Core
	LS-D7C	4 – 6 feet	16-Oct-13, 15:00	Composite Core
	LS-D7D	6 – 8 feet	16-Oct-13, 15:00	Composite Core
	LS-D7E	8 – 10 feet	16-Oct-13, 15:00	Composite Core
LS-D8	LS-D8A	0 – 2 feet	16-Oct-13, 13:00	Composite Core
	LS-D8B	2 – 4 feet	16-Oct-13, 13:00	Composite Core
	LS-D8C	4 – 6 feet	16-Oct-13, 13:00	Composite Core
	LS-D8D	6 – 8 feet	16-Oct-13, 13:00	Composite Core
	LS-D8E	8 – 10 feet	16-Oct-13, 13:00	Composite Core

Table 3. Geo-references locations where additional sediment/soil samples were collected at the proposed Little Sioux project site.

Site	Latitude	Longitude	Depth to Water Table
LS-D1	41° 47’ 17.7”	96° 04’ 02.7”	5 feet
LS-D2	41° 47’ 10.3”	96° 04’ 03.4”	3 feet
LS-D3	41° 47’ 04.2”	96° 04’ 10.7”	>10 feet
LS-D4	41° 46’ 58.8”	96° 04’ 17.0”	9 feet
LS-D5	41° 46’ 50.6”	96° 04’ 20.6”	3 feet
LS-D6	41° 46’ 44.2”	96° 04’ 27.6”	3 feet
LS-D7	41° 46’ 39.1”	96° 04’ 31.3”	6 feet
LS-D8	41° 46’ 33.5”	96° 04’ 32.5”	6 feet

Table 4. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D1 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D1A (0-2 ft)	0.0	0.0	0.0	0.1	7.2	79.9	11.8	1.0	92.9
LS-D1B (2-4 ft)	0.0	0.0	0.0	0.5	36.3	58.3	3.9	1.0	95.7
LS-D1C (4-6 ft)	0.0	0.0	0.0	0.1	13.3	71.5	13.7	1.4	82.2
LS-D1D (6-8 ft)	0.0	0.0	0.0	0.0	5.0	42.1	48.9	4.0	75.6
LS-D1E (8-10 ft)	0.0	0.0	0.0	0.0	6.2	61.2	30.5	2.1	75.7
MEAN	**0.0**	**0.0**	**0.0**	**0.1**	**13.6**	**62.6**	**21.8**	**1.9**	**84.4**

Depth to groundwater = 5 feet.

See Table 12 for definition of particle sizes.

Table 5. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D2 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D2A (0-2 ft)	0.0	0.0	0.0	0.0	0.3	32.9	55.2	11.6	82.8
LS-D2B (2-4 ft)	0.0	0.0	0.0	0.0	0.1	61.0	36.1	2.8	73.1
LS-D2C (4-6 ft)	0.0	0.0	0.0	0.0	0.2	72.5	25.4	1.9	74.0
LS-D2D (6-8 ft)	0.0	0.0	0.0	0.0	0.1	88.9	10.0	1.0	73.8
MEAN	**0.0**	**0.0**	**0.0**	**0.0**	**0.2**	**63.8**	**31.7**	**4.3**	**78.4**

Depth to groundwater = 3 feet.

Only collected sediment/soil sample to a depth of 8 feet – bore hole side walls collasped in saturated zone.

See Table 12 for definition of particle sizes.

Table 6. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D3 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D3A (0-2 ft)	0.0	0.0	0.0	0.0	0.1	38.8	53.2	7.9	87.6
LS-D3B (2-4 ft)	0.0	0.0	0.0	0.0	2.0	86.4	10.6	1.0	95.9
LS-D3C (4-6 ft)	0.0	0.0	0.0	0.0	1.3	95.1	2.3	1.3	97.7
LS-D3D (6-8 ft)	0.0	0.0	0.0	0.0	1.2	95.4	2.1	1.3	97.1
LS-D3E (8-10 ft)	0.0	0.0	0.0	0.0	1.5	92.4	4.8	1.3	90.6
MEAN	**0.0**	**0.0**	**0.0**	**0.0**	**1.2**	**81.6**	**14.6**	**2.6**	**93.8**

Depth to groundwater = >10 feet.

See Table 12 for definition of particle sizes.

Table 7. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D4 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D4A (0-2 ft)	0.0	0.0	0.0	0.0	4.7	50.1	33.7	11.5	90.9
LS-D4B (2-4 ft)	0.0	0.0	0.4	0.1	5.4	88.8	4.0	1.3	97.3
LS-D4C (4-6 ft)	0.0	0.0	0.0	0.0	4.3	92.1	2.6	1.0	97.1
LS-D4D (6-8 ft)	0.0	0.0	0.0	0.0	6.7	89.7	2.2	1.4	90.0
LS-D4E (8-10 ft)	0.0	0.0	0.0	0.0	4.6	87.9	6.5	1.0	76.1
MEAN	**0.0**	**0.0**	**0.1**	**0.0**	**5.1**	**81.7**	**9.8**	**3.2**	**90.3**

Depth to groundwater = 9 feet.

See Table 12 for definition of particle sizes.

Table 8. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D5 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D5A (0-2 ft)	0.0	0.0	0.0	0.0	4.5	76.3	15.5	3.7	83.0
LS-D5B (2-4 ft)	0.0	0.0	0.0	0.6	12.9	83.4	2.1	1.0	80.2
LS-D5C (4-6 ft)	0.0	0.0	0.0	0.0	5.7	90.6	2.7	1.0	78.7
MEAN	**0.0**	**0.0**	**0.0**	**0.2**	**7.7**	**83.4**	**6.8**	**1.9**	**80.7**

Depth to groundwater = 3 feet.

Only collected sediment/soil sample to a depth of 6 feet – bore hole side walls collasped in saturated zone.

See Table 12 for definition of particle sizes.

Table 9. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D6 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D6A (0-2 ft)	0.0	0.0	0.0	0.0	3.0	64.1	23.8	9.1	91.1
LS-D6B (2-4 ft)	0.0	0.0	0.0	0.0	0.9	75.7	19.2	4.2	79.4
LS-D6C (4-6 ft)	0.0	0.0	0.0	0.0	0.8	24.7	57.1	17.4	72.7
LS-D6D (6-8 ft)	0.0	0.0	0.0	0.0	2.1	47.9	41.4	8.6	72.5
LS-D6E (8-10 ft)	0.0	0.0	0.0	0.0	3.4	58.2	30.7	7.7	76.6
MEAN	**0.0**	**0.0**	**0.0**	**0.0**	**2.0**	**54.1**	**34.4**	**9.4**	**78.5**

Depth to groundwater = 3 feet.

See Table 12 for definition of particle sizes.

Table 10. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D7 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D7A (0-2 ft)	0.0	0.0	0.0	0.0	0.4	68.3	27.7	3.6	86.1
LS-D7B (2-4 ft)	0.0	0.0	0.0	0.0	5.7	84.9	8.4	1.0	95.1
LS-D7C (4-6 ft)	0.0	0.0	0.0	0.3	27.0	69.2	2.5	1.0	96.3
LS-D7D (6-8 ft)	0.0	0.0	0.0	0.7	24.7	70.4	3.2	1.0	88.6
LS-D7E (8-10 ft)	0.0	0.0	0.0	0.3	18.4	75.7	4.6	1.0	80.0
MEAN	**0.0**	**0.0**	**0.0**	**0.3**	**15.2**	**73.7**	**9.3**	**1.5**	**89.2**

Depth to groundwater = 6 feet.

See Table 12 for definition of particle sizes.

Table 11. Summary of particle size and percent solids analyses of the sediment/soil samples collected at site LS-D8 at the proposed Little Sioux project site.

Sample ID	% Cobbles	% Gravel		% Sand			% Fines		% Solids
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	
LS-D8A (0-2 ft)	0.0	0.0	0.0	0.0	0.2	57.1	33.9	8.8	85.2
LS-D8B (2-4 ft)	0.0	0.0	0.0	0.0	0.0	23.1	64.7	12.2	82.8
LS-D8C (4-6 ft)	0.0	0.0	0.0	0.0	0.0	53.1	41.1	5.8	89.2
LS-D8D (6-8 ft)	0.0	0.0	0.0	0.0	0.0	27.0	63.5	9.5	77.8
LS-D8E (8-10 ft)	0.0	0.0	0.0	0.0	0.0	51.9	44.2	3.9	76.3
MEAN	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**42.4**	**49.5**	**8.0**	**82.2**

Depth to groundwater = 6 feet.

See Table 12 for definition of particle sizes.

Table 12. Size ranges for defined sediment/soil particle size cateogies.

Cobbles	Gravel		Sand			Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
< 76,200µ	76,200µ to 19,050µ	19,050µ to 4,760µ	4,760µ to 2,000µ	2,000µ to 400µ	400µ to 200µ	200µ to 2µ	> 2µ
< 76.2mm	76.2mm to 19.1mm	19.1mm to 4.8mm	4.8mm to 2mm	2mm to 0.4mm	0.4mm to 0.2mm	0.2mm to 0.002mm	> 0.002mm

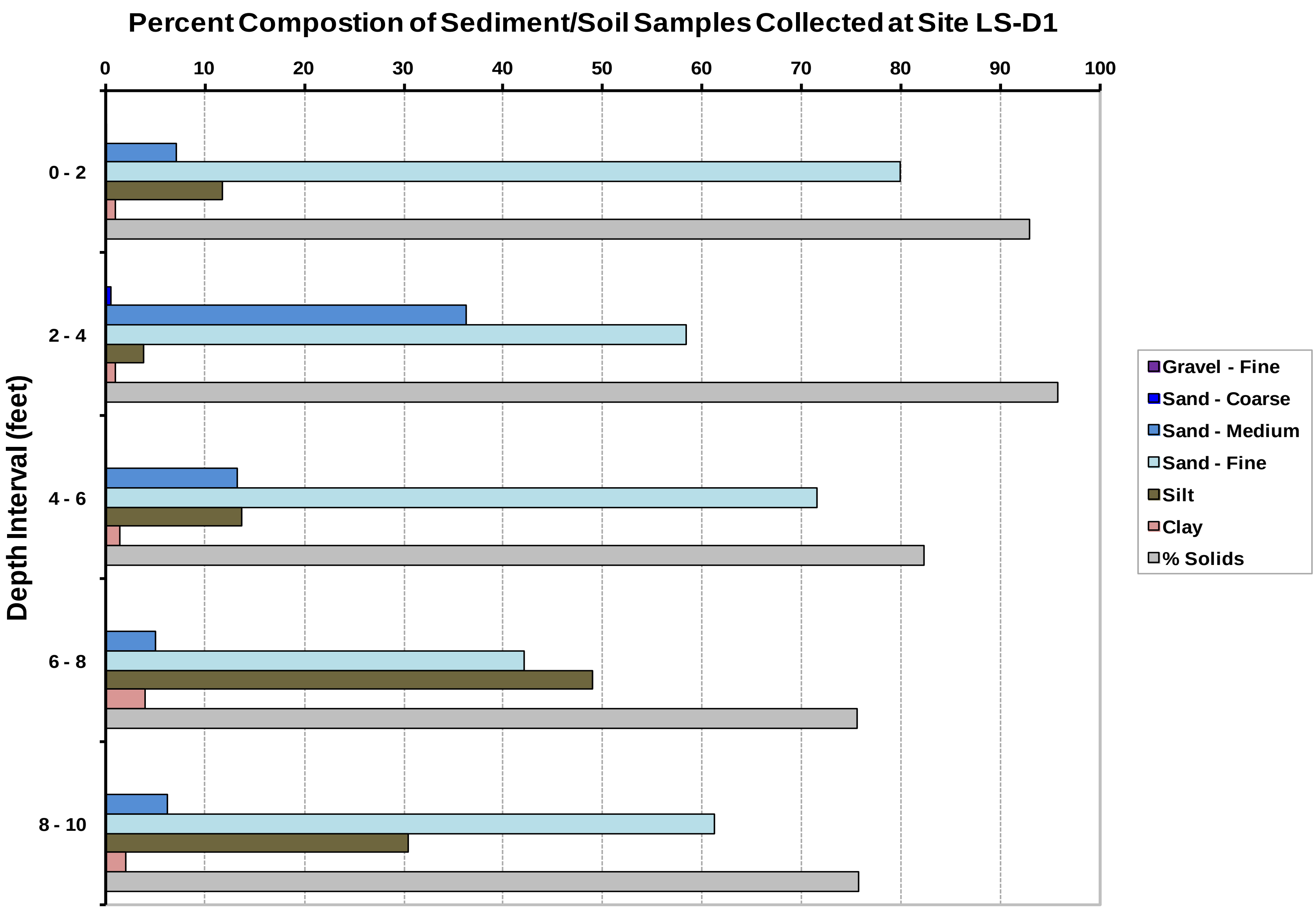


Figure 6. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D1.

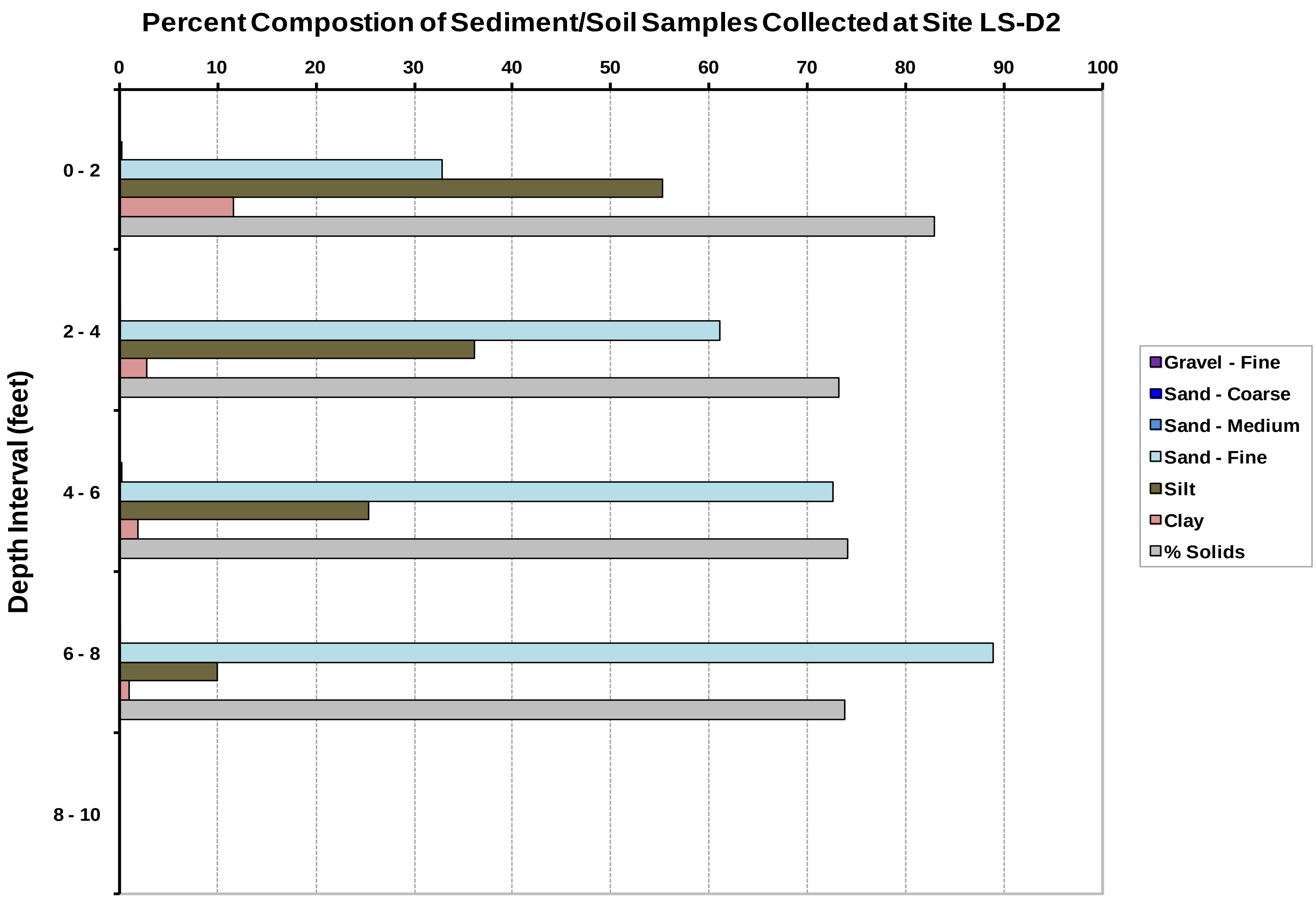


Figure 7. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D2.

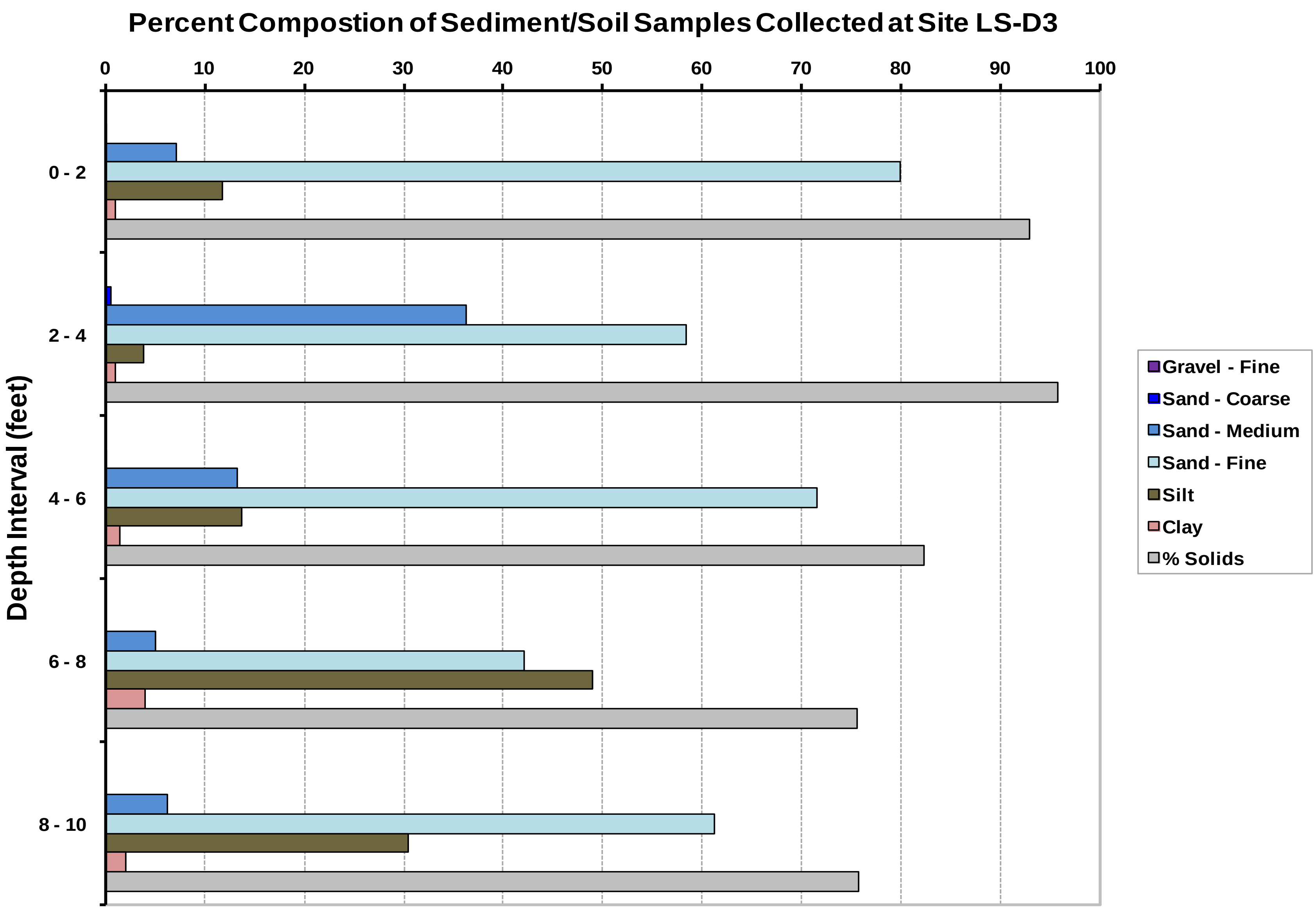


Figure 8. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D3.

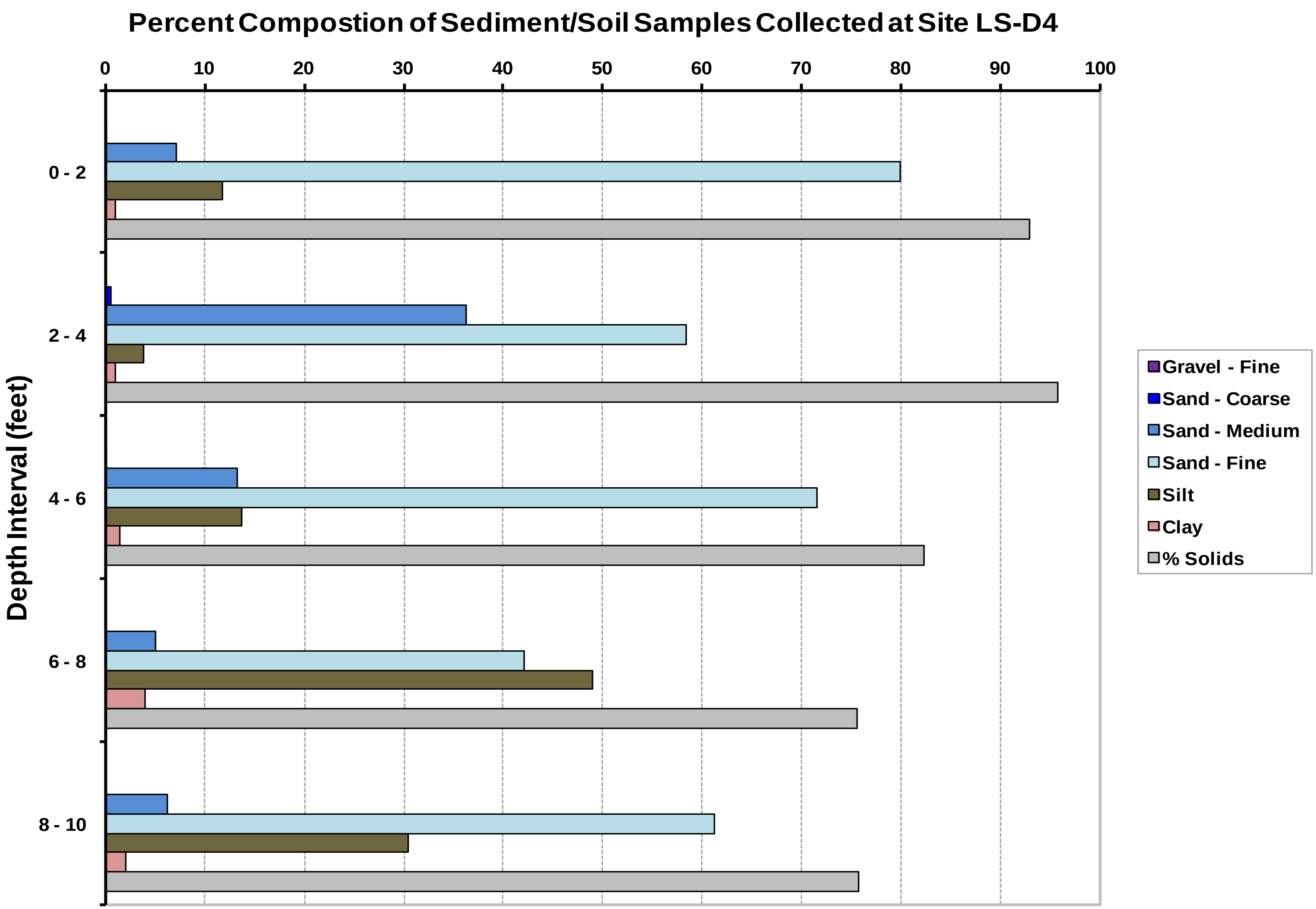


Figure 9. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D4.

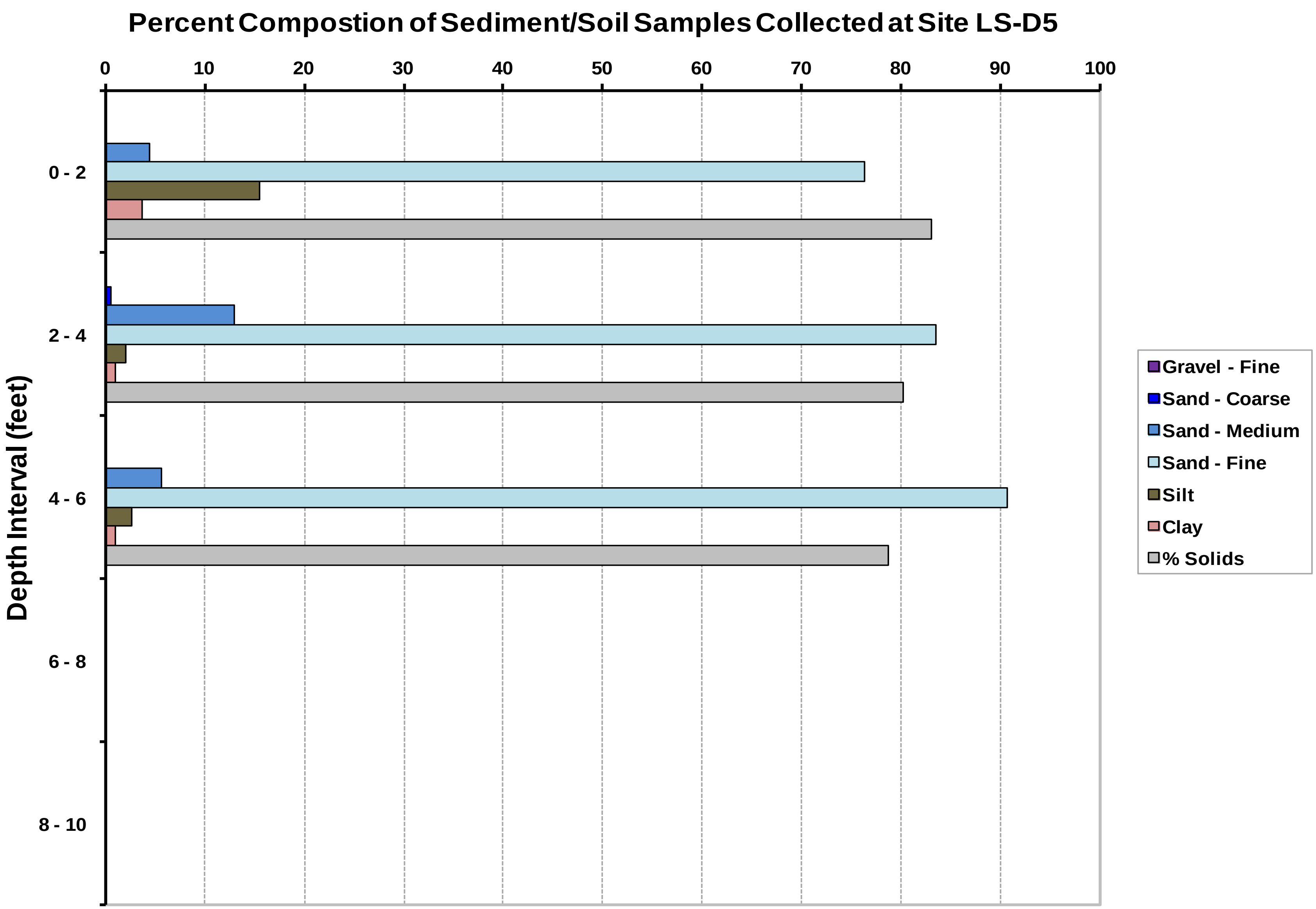


Figure 10. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D5.

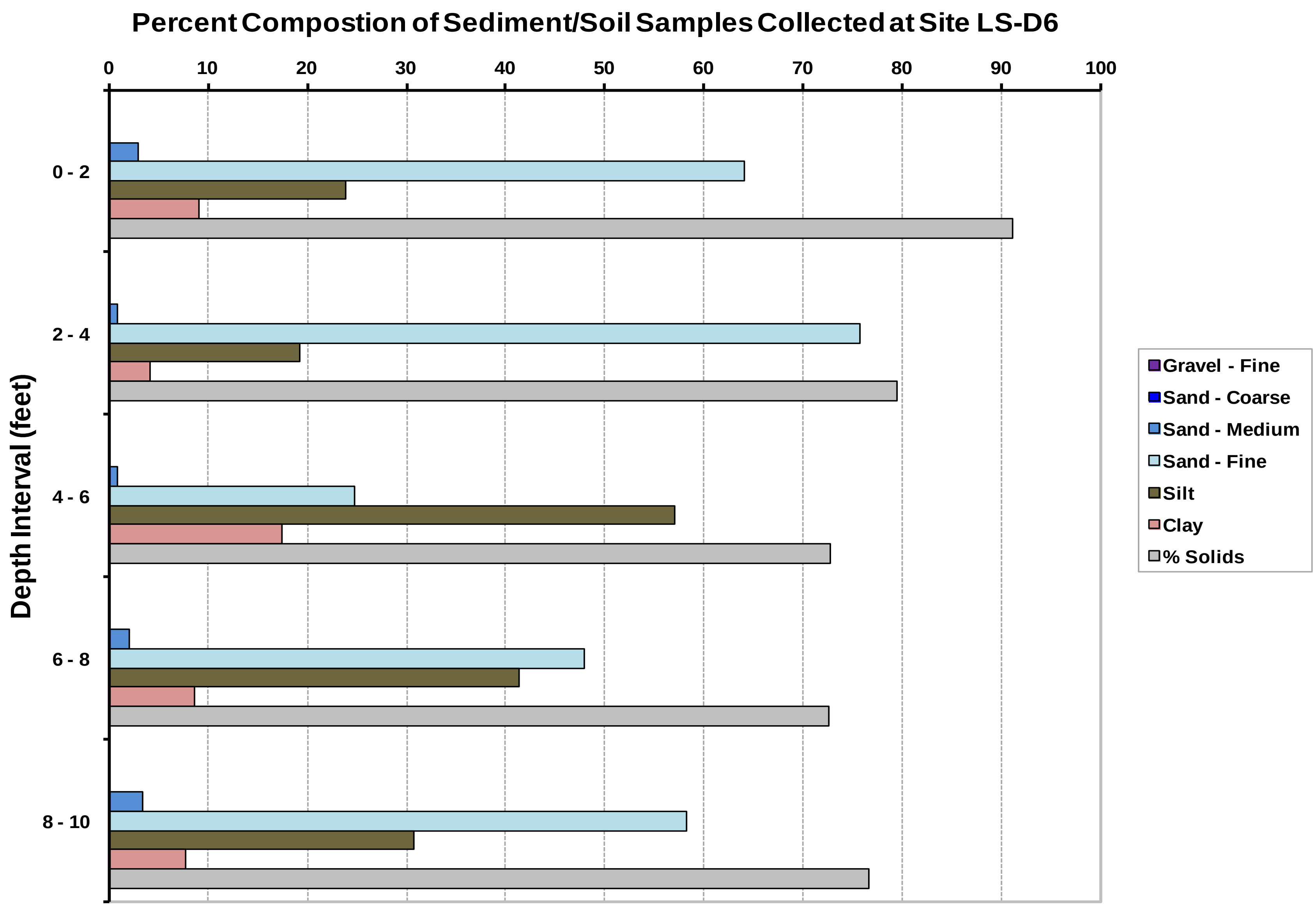


Figure 11. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D6.

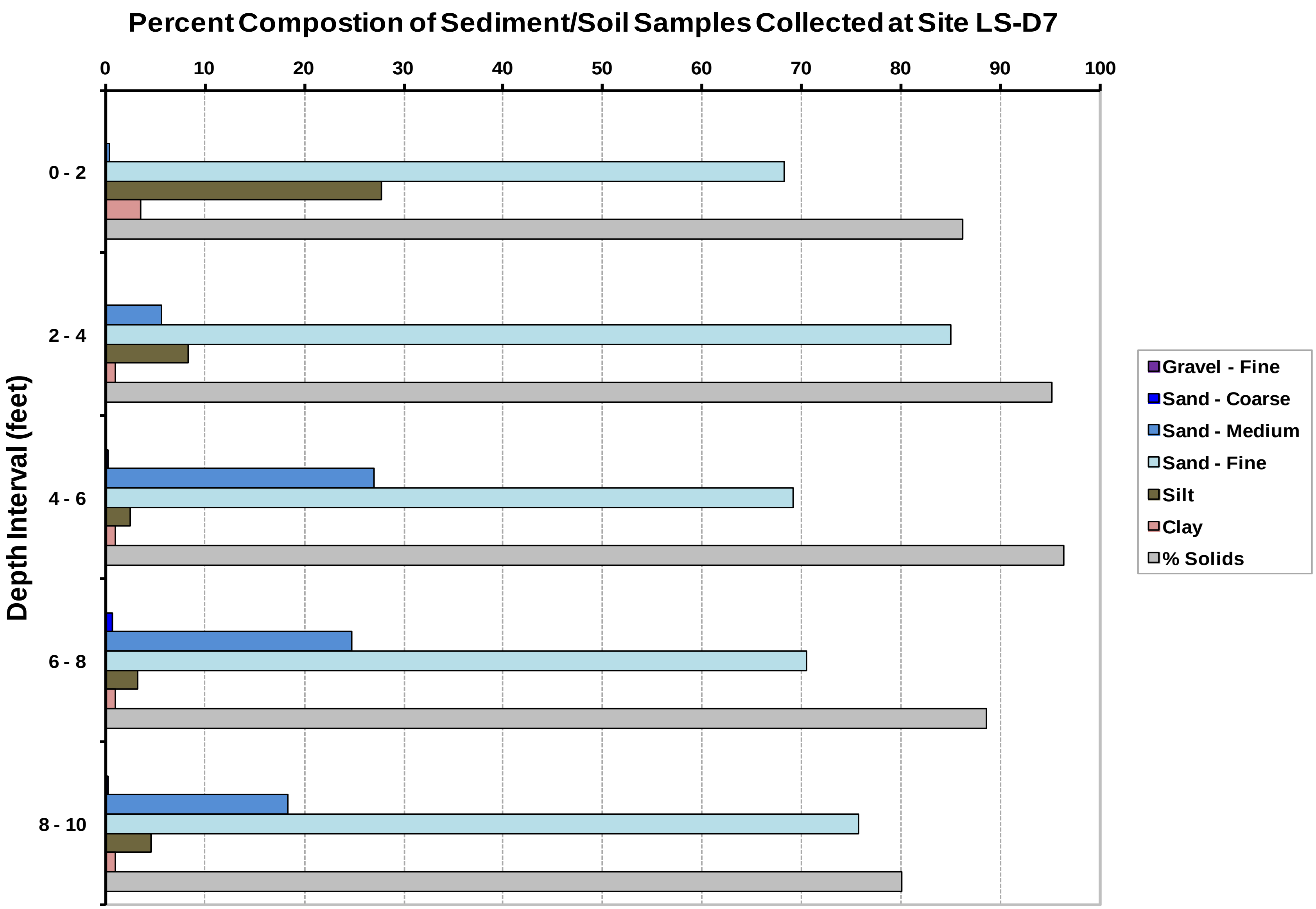


Figure 12. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D7.

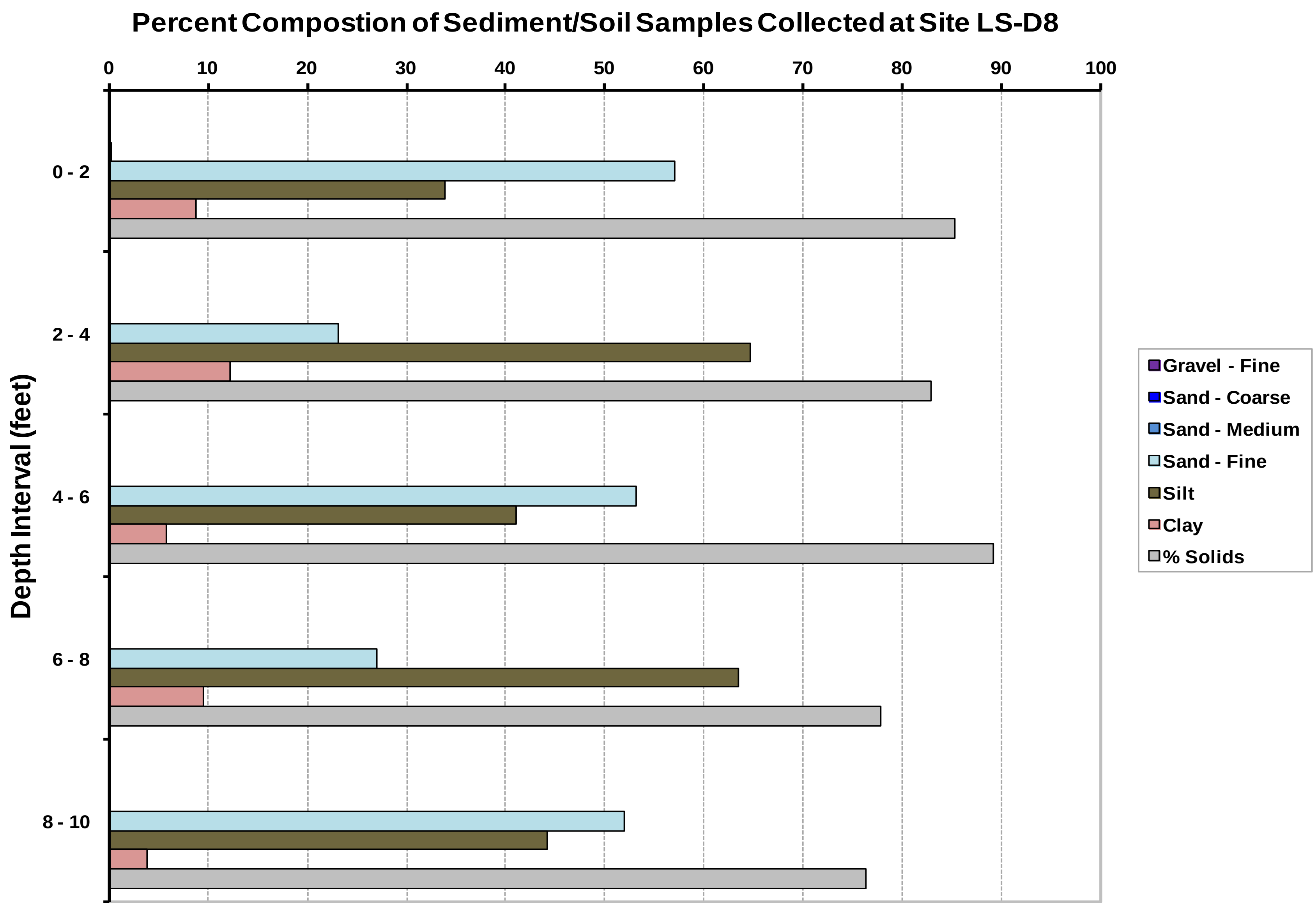


Figure 13. Percent particle size (dry wt.) and percent solids of depth-increment sediment/soil samples collected at site LS-D8.

Table 13. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D1 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D1A (0-2 ft)	205	1.1	380
LS-D1B (2-4 ft)	81	1.2	295
LS-D1C (4-6 ft)	159	1.3	370
LS-D1D (6-8 ft)	398	<0.05	471
LS-D1E (8-10 ft)	223	<0.05	435
MEAN	**213**	**0.7**	**390**

Depth to Groundwater = 5 feet.

Table 14. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D2 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D2A (0-2 ft)	1,070	2.3	576
LS-D2B (2-4 ft)	235	<0.04	467
LS-D2C (4-6 ft)	349	<0.05	500
LS-D2D (6-8 ft)	136	<0.05	418
MEAN	**448**	**0.6**	**490**

Depth to Groundwater = 3 feet.
Only collected sediment/soil sampled to a depth of 8 feet – bore hole side walls collasped in saturated zone.

Table 15. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D3 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D3A (0-2 ft)	613	<0.04	578
LS-D3B (2-4 ft)	195	<0.04	381
LS-D3C (4-6 ft)	68	<0.04	343
LS-D3D (6-8 ft)	74	<0.04	332
LS-D3E (8-10 ft)	120	<0.04	388
MEAN	**214**	**<0.04**	**404**

Depth to Groundwater = >10 feet.

Table 16. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D4 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D4A (0-2 ft)	681	<0.04	519
LS-D4B (2-4 ft)	110	<0.04	356
LS-D4C (4-6 ft)	52	<0.04	331
LS-D4D (6-8 ft)	64	<0.04	322
LS-D4E (8-10 ft)	77	<0.05	318
MEAN	**197**	**<0.05**	**369**

Depth to Groundwater = 9 feet.

Table 17. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D5 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D5A (0-2 ft)	181	<0.04	449
LS-D5B (2-4 ft)	73	<0.04	294
LS-D5C (4-6 ft)	121	<0.04	374
MEAN	**125**	**<0.04**	**372**

Depth to Groundwater = 3 feet.
Only collected sediment/soil sampled to a depth of 6 feet – bore hole side walls collasped in saturated zone.

Table 18. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D6 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D6A (0-2 ft)	563	1.5	481
LS-D6B (2-4 ft)	290	1.4	409
LS-D6C (4-6 ft)	769	<0.05	624
LS-D6D (6-8 ft)	652	<0.05	584
LS-D6E (8-10 ft)	387	<0.05	516
MEAN	**532**	**0.6**	**523**

Depth to Groundwater = 3 feet.

Table 19. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D7 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D7A (0-2 ft)	143	<0.04	461
LS-D7B (2-4 ft)	82	<0.04	351
LS-D7C (4-6 ft)	75	<0.04	276
LS-D7D (6-8 ft)	66	<0.04	271
LS-D7E (8-10 ft)	65	<0.04	332
MEAN	**86**	**<0.04**	**338**

Depth to Groundwater = 6 feet.

Table 20. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D8 at the proposed Little Sioux project site.

Sample ID	Total Kjeldahl Nitrogen (mg/kg dry wt.)	Nitrate-Nitrite Nitrogen (mg/kg dry wt.)	Total Phosphorus (mg/kg dry wt.)
LS-D8A (0-2 ft)	585	2.6	552
LS-D8B (2-4 ft)	499	2.4	575
LS-D8C (4-6 ft)	261	<0.04	503
LS-D8D (6-8 ft)	440	<0.05	575
LS-D8E (8-10 ft)	288	<0.05	501
MEAN	**415**	**1.0**	**541**

Depth to Groundwater = 6 feet.

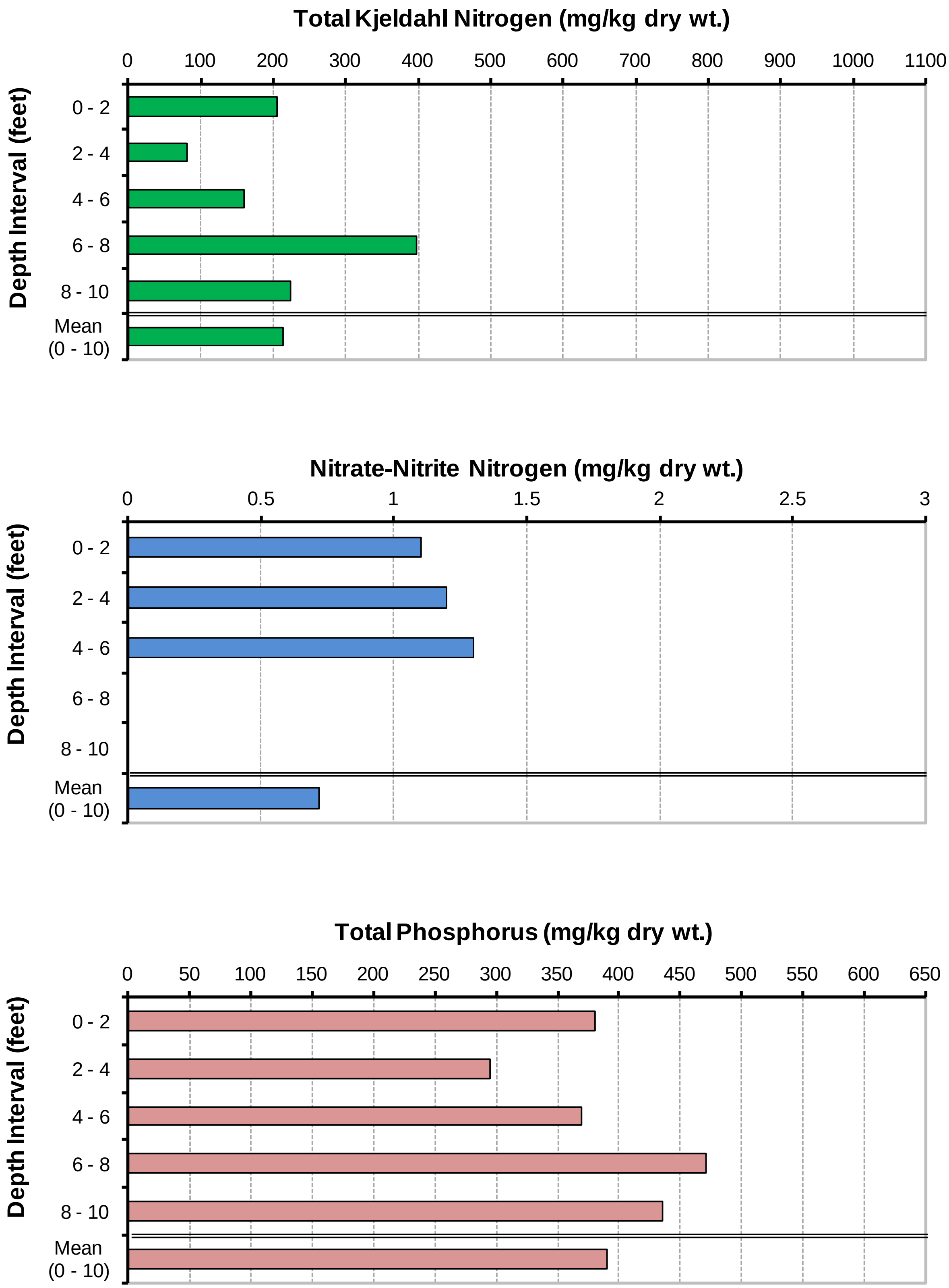


Figure 14. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D1.

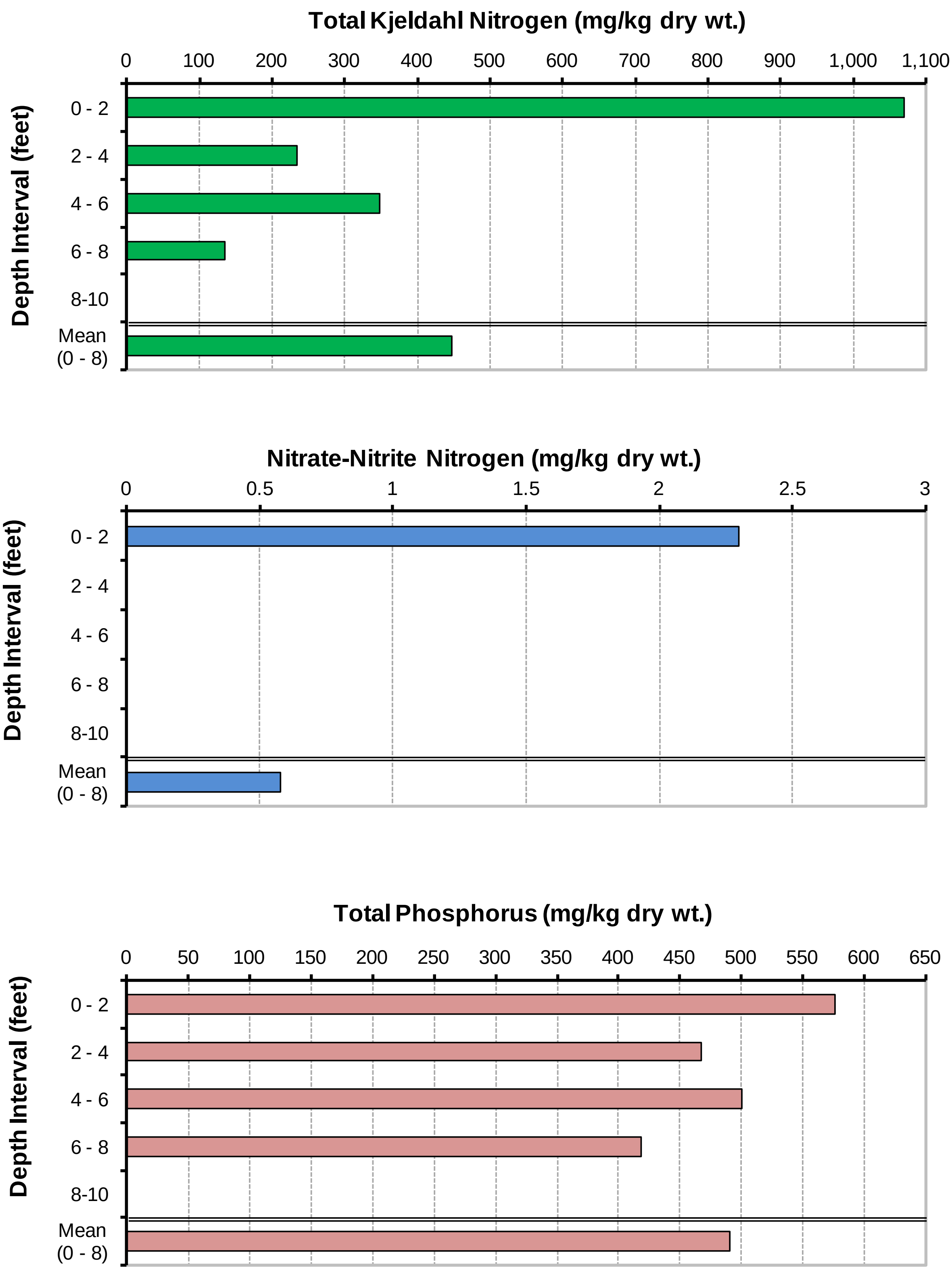


Figure 15. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D2.

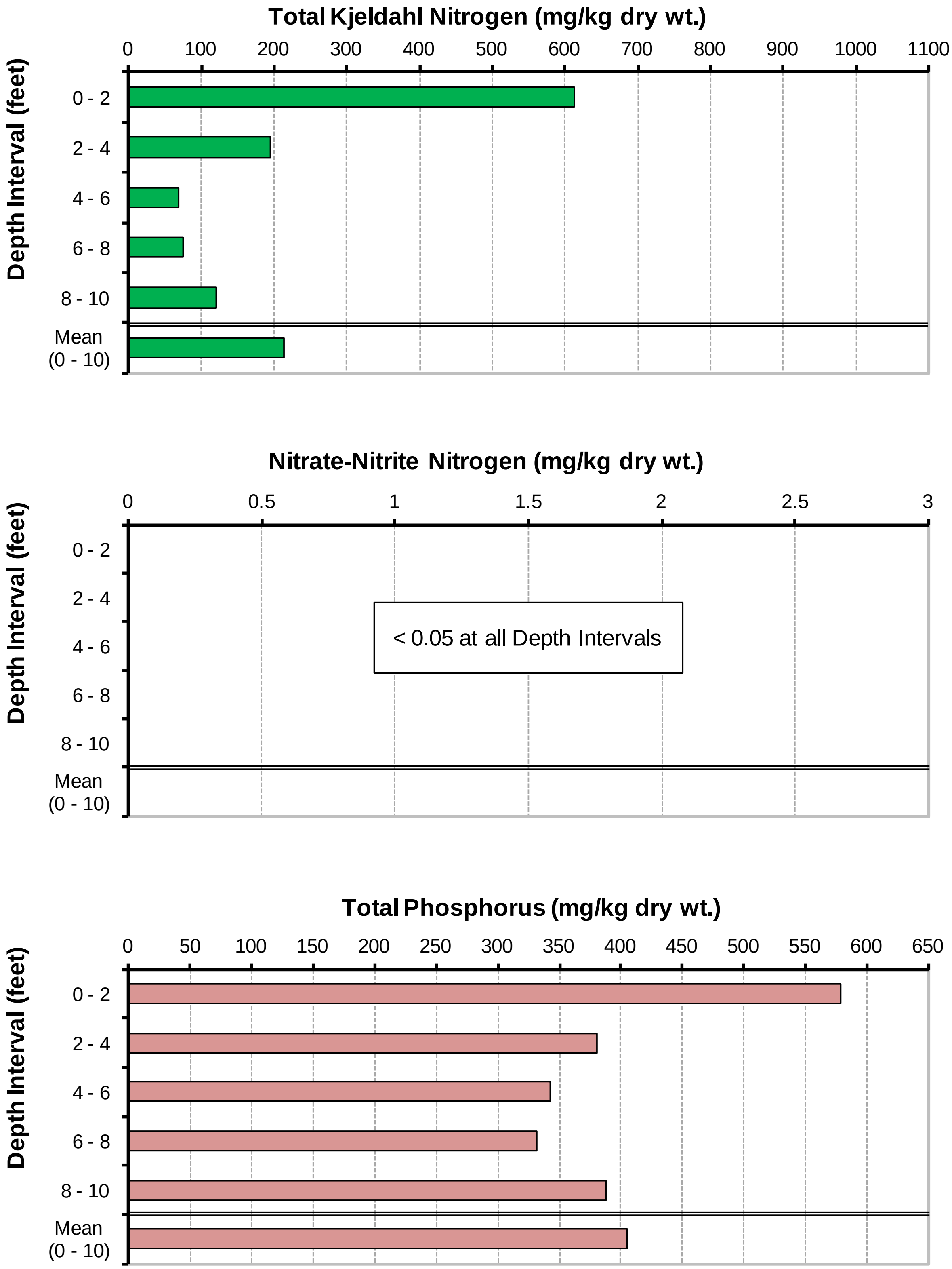


Figure 16. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D3.

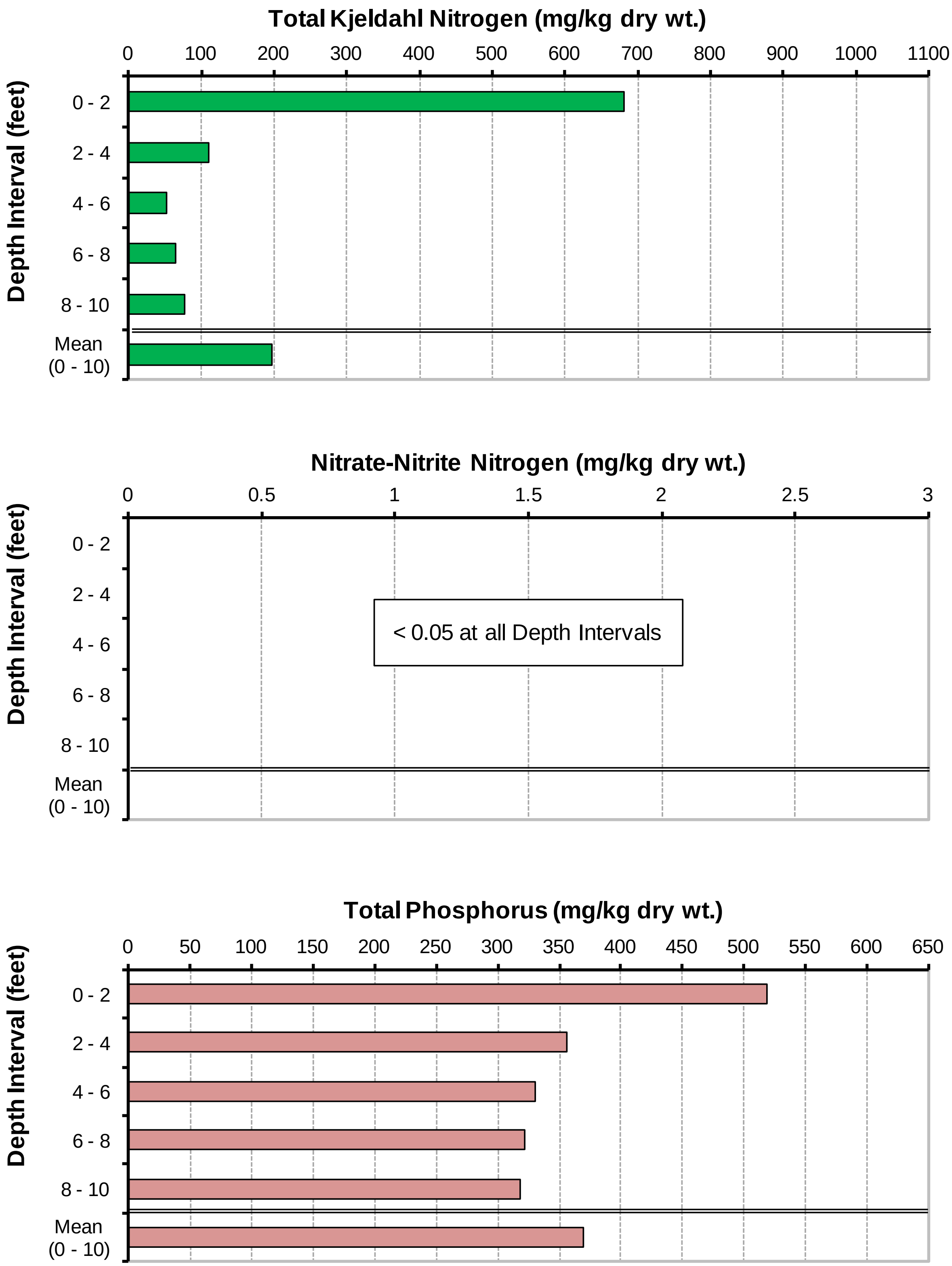


Figure 17. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D4.

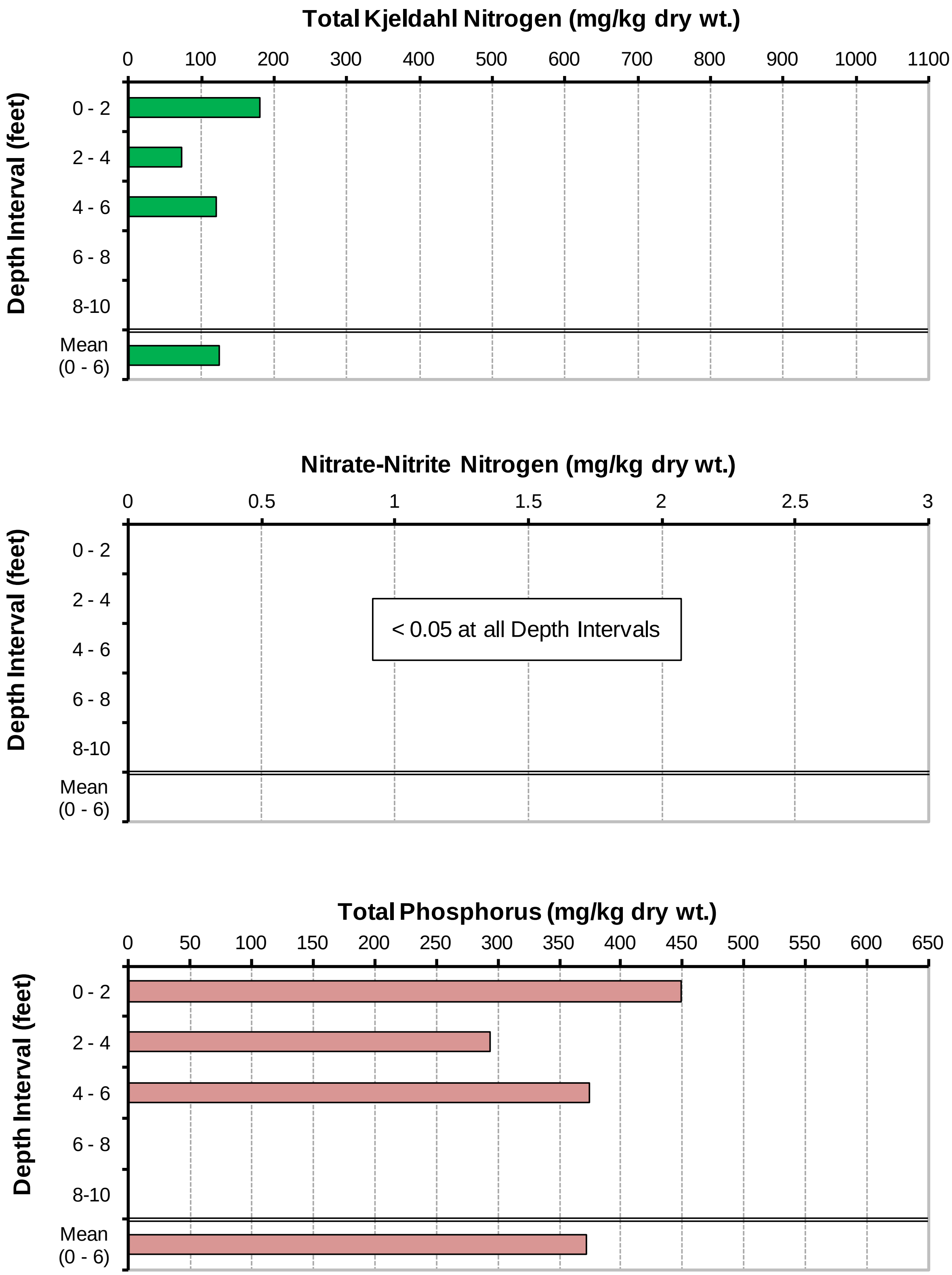
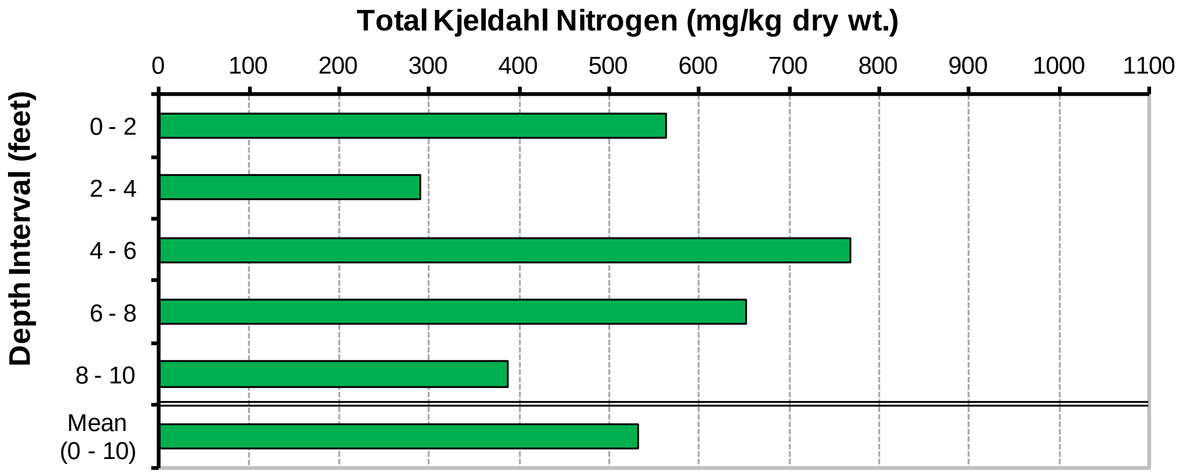
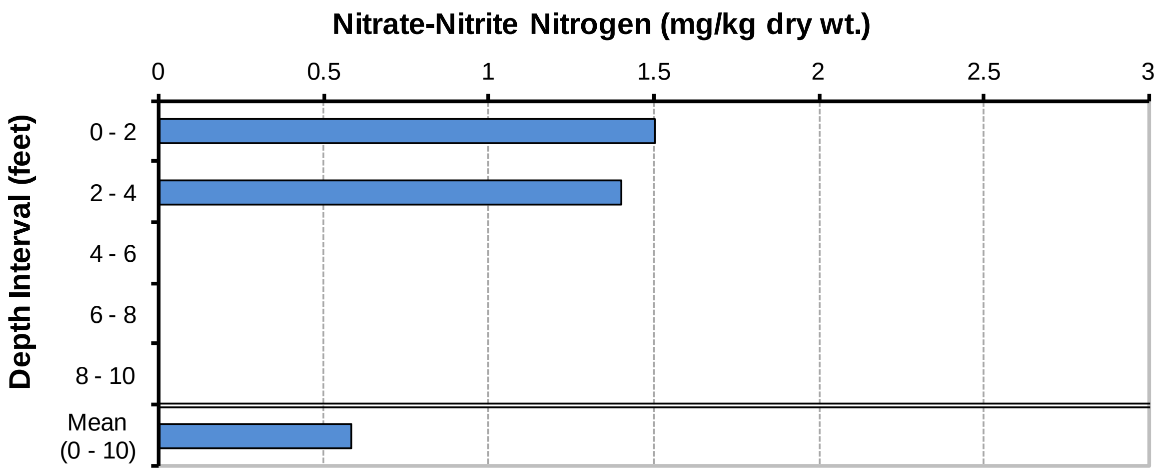


Figure 18. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D5.





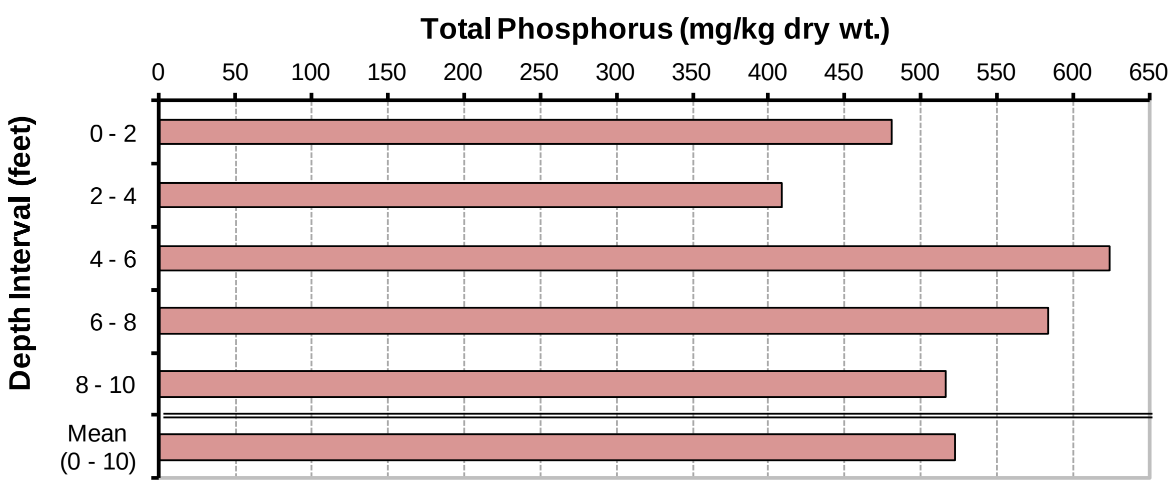


Figure 19. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D6.

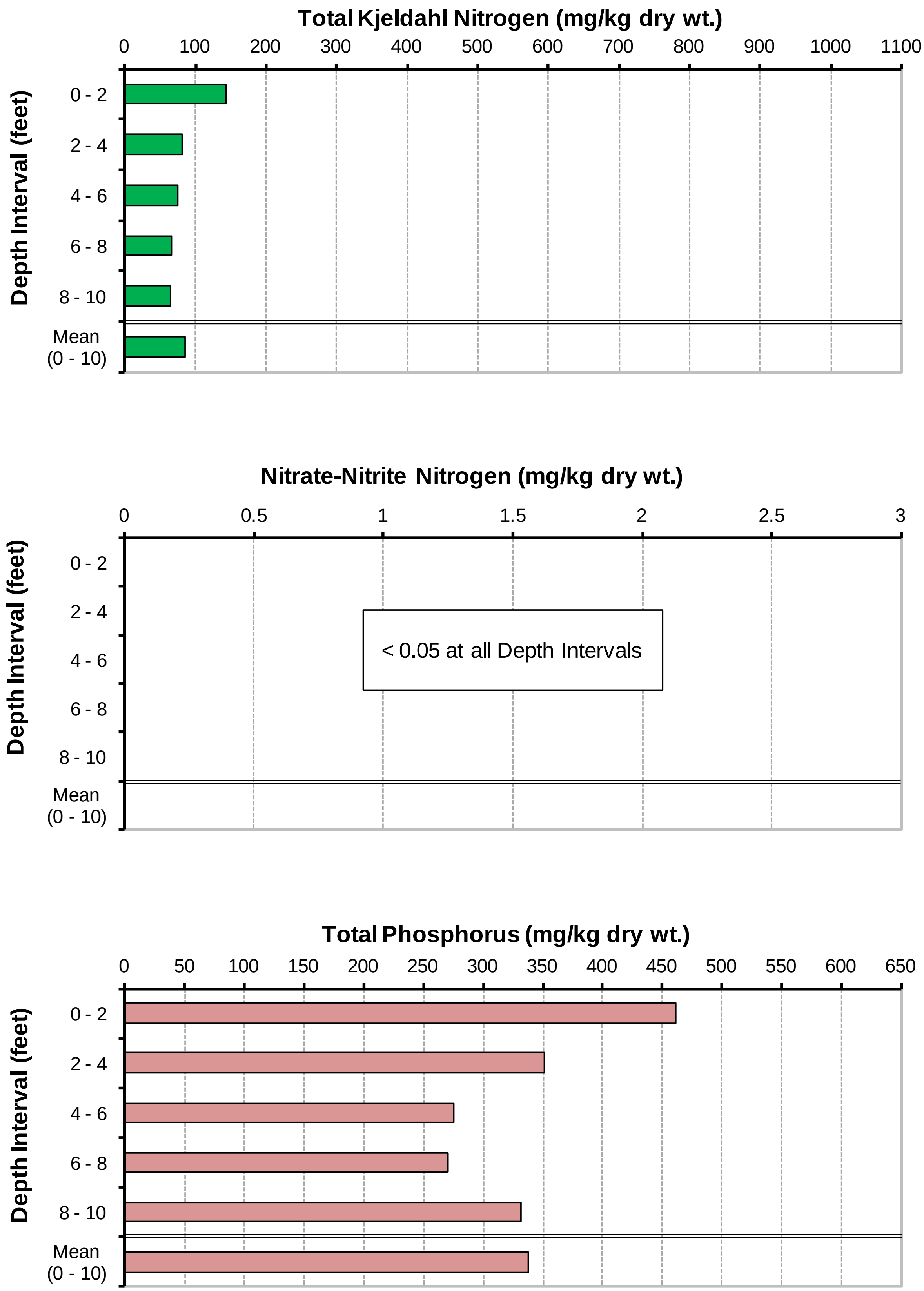


Figure 20. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D7.

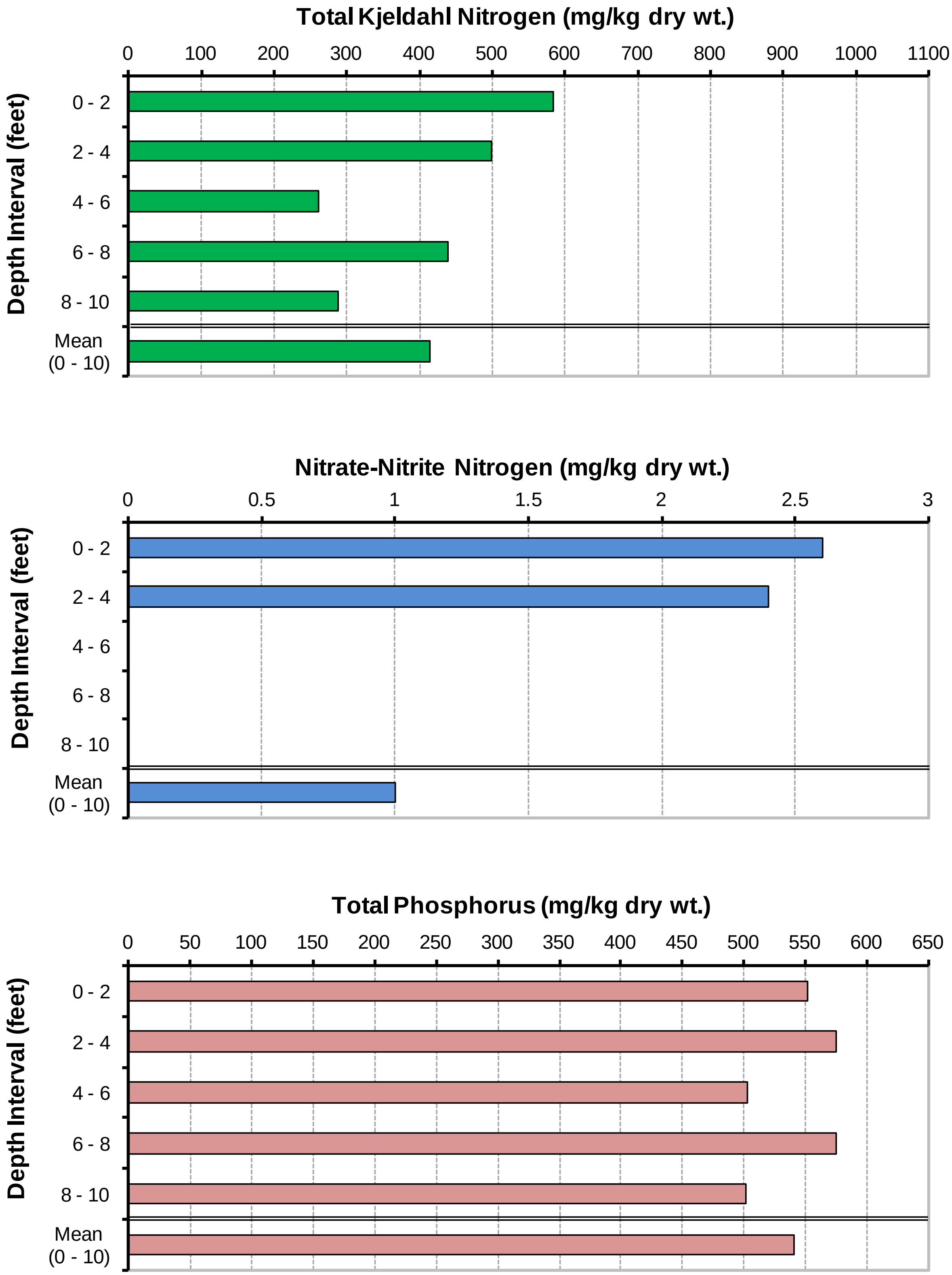


Figure 21. Summary of nutrient analyses of the sediment/soil samples collected at site LS-D8.

4 DISCUSSION

4.1 Comparison of Nutrient Levels Measured at the Proposed Little Sioux Project Site

4.1.1 Total Phosphorus

A data matrix of the measured sediment/soil total phosphorus levels in the 37 samples collected among the eight sampling sites and five depth increments is provided in Table 21. Figure 22 provides a boxplot of the measured sediment/soil total phosphorus levels by sampling sites, and Figure 23 provides a boxplot of the measured sediment/soil total phosphorus levels by depth increment. Boxplots were constructed using the MINITAB statistical software.

Table 21. Data matrix for measured sediment/soil total phosphorus levels.

Depth Increment (ft)	Site							
	LS-D1	**LS-D2**	**LS-D3**	**LS-D4**	**LS-D5**	**LS-D6**	**LS-D7**	**LS-D8**
0 – 2	380	576	578	519	449	481	461	552
2 – 4	295	467	381	356	294	409	351	575
4 – 6	370	500	343	331	374	624	276	503
6 – 8	471	418	332	322	*	584	271	575
8 – 10	435	*	388	318	*	516	332	501

* Grid cell not sampled due to bore hole collapse.

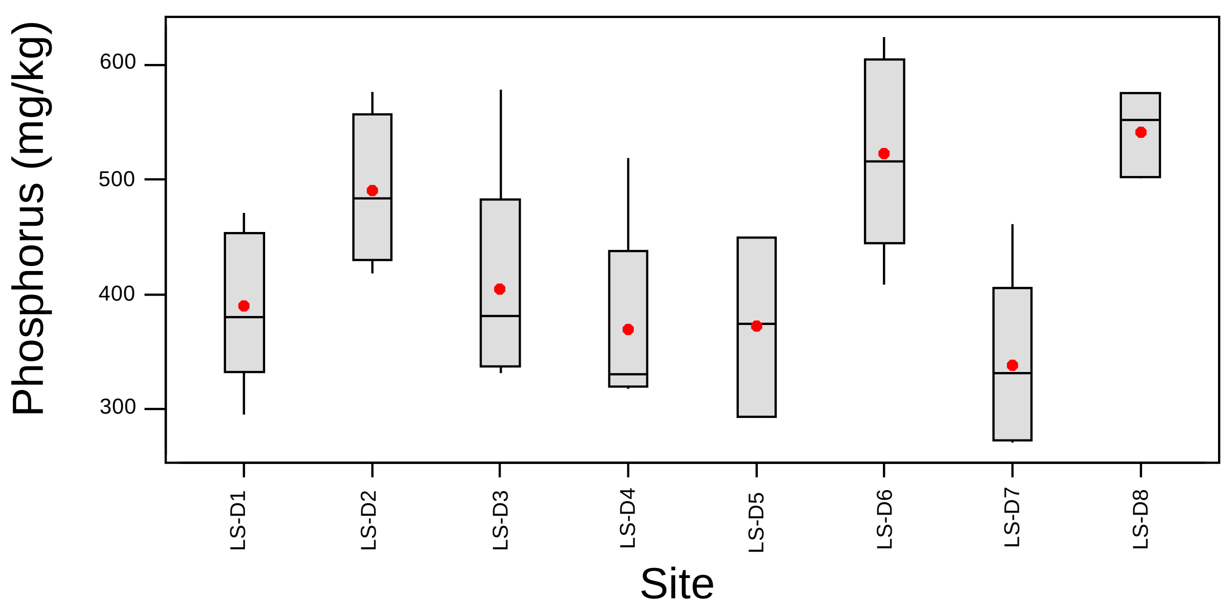


Figure 22. Boxplots of sediment/soil total phosphorus levels measured at the eight sampled sites. [Note: The box represents the middle 50% of the data. The line through the box represents the median. The lines (whiskers) extending from the box represent the upper and lower 25% of the data excluding outliers. Outliers, if present, are represented by asterisks (*). The red point on each plot represents the mean.]

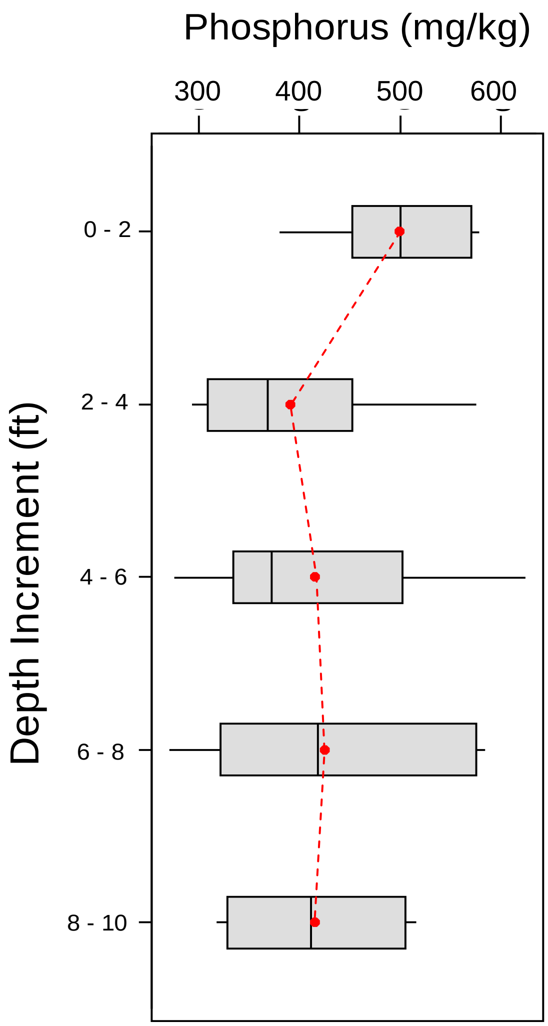


Figure 23. Boxplots of sediment/soil total phosphorus levels measured at the eight sampled sites by the composited depth increments. [Note: See Figure 22 for explanation of boxplot. The red dashed line represents the total phosphorus depth profile plotted by connecting means of the depth increments.]

4.1.1.1 __Do Total Phosphorus Levels Significantly Vary Spatially and with Depth at the Proposed Little Sioux Project Area?__

The following hypotheses and alternative null hypotheses were tested:

$H1_o$: Total phosphorus levels measured at the eight sampled locations are significantly different.

$H1_a$: Total phosphorus levels measured at the eight sampled locations are not significantly different.

$H2_o$: Total phosphorus levels measured at different depth increments are significantly different – i.e. measured total phosphorus levels are significantly different with depth.

$H2_a$: Total phosphorus levels measured at different depth increments are not significantly different – i.e. measured total phosphorus levels are not significantly different with depth.

4.1.1.2 Two-Way Analysis of Variance (ANOVA)

A Two-Way ANOVA with the response variable as total phosphorus and the two factors of site and depth increment was not able to be applied due to the missing depth increment data at site LS-D2 (8-10 feet) and site LS-D5 (6-8 and 8-10 feet) (Table 21).

4.1.1.3 One-Way ANOVA

A One-Way ANOVA was applied to the total phosphorus data matrix (Table 21). The response variable is total phosphorus and the factors evaluated separately are site and depth increment.

4.1.1.3.1 One-Way ANOVA Total Phosphorus versus Site

Table 22 provides the One-Way ANOVA results for total phosphorus versus site. Based on the premise that non-overlapping 95% confidence intervals indicate a significant difference, measured sediment/soil total phosphorus levels at 10 of the possible 28 comparisons of sites are significantly different (Table 23).

Table 22. One-way ANOVA results: Phosphorus versus Site

Source	DF	SS	MS	F	P
Site	7	201,119	28,743	4.90	0.001
Error	29	170,099	5,865		
Total	36	371,298			

Comparison of Sites:

```
                                         Individual 95% CIs For Mean
                                             Based on Pooled StDev
Site         N      Mean     StDev     ----+---------+---------+---------+--
LS-D1        5    390.20     67.29           (------*------)
LS-D2        4    490.25     66.35                    (-------*-------)
LS-D3        5    404.40     99.96            (------*------)
LS-D4        5    369.20     85.03         (------*------)
LS-D5        3    372.33     77.51       (--------*--------)
LS-D6        5    522.80     84.75                        (------*------)
LS-D7        5    338.20     76.92      (------*------)
LS-D8        5    541.20     37.00                       (------*------)
                                       ----+---------+---------+---------+--
Pooled StDev =     76.59                 300       400       500       600
```

Table 23. Comparison of measured sediment/soil total phosphorus levels at the eight sampled sites for significant differences.

	LS-D1	LS-D2	LS-D3	LS-D4	LS-D5	LS-D6	LS-D7
LS-D2	No						
LS-D3	No	No					
LS-D4	No	No	No				
LS-D5	No	No	No	No			
LS-D6	Yes	No	No	Yes	Yes		
LS-D7	No	Yes	No	No	No	Yes	
LS-D8	Yes	No	Yes	Yes	Yes	No	Yes

Note: No and Yes indicate the presence of a significant difference based on non-overlapping 95% confidence intervals.

4.1.1.3.2 One-Way ANOVA Total Phosphorus versus Depth Increment

Table 24 provides the One-Way ANOVA results for total phosphorus versus depth increment. Based on the premise that non-overlapping 95% confidence intervals indicate a significant difference, measured sediment/soil total phosphorus levels at none of the possible 10 comparisons of depth increments are significantly different (Table 25).

Table 24. One-way ANOVA results: Phosphorus versus Depth Increment.

Source	DF	SS	MS	F	P
Site	4	54,126	13,531	1.37	0.268
Error	32	317,172	9,912		
Total	36	371,298			

Comparison of Depth Increments:

```
                                            Individual 95% CIs For Mean
                                                Based on Pooled StDev
Depth       N     Mean      StDev     -----+---------+---------+---------+-
 0-2        8    499.50     69.49                     (---------*----------)
 2-4        8    391.00     93.74      (---------*---------)
 4-6        8    415.13    115.83         (---------*----------)
 6-8        7    424.71    124.45          (----------*----------)
 8-10       6    415.00     83.69       (-----------*-----------)
                                      -----+---------+---------+---------+-
Pooled StDev =   99.56                    350       420       490       560
```

Table 25. Comparison of measured sediment/soil total phosphorus levels at the five sampled depth increments for significant differences.

	0 – 2 ft	2 – 4 ft	4 -6 ft	6 – 8 ft
2 – 4 ft	No			
4 – 6 ft	No	No		
6 – 8 ft	No	No	No	
8 – 10 ft	No	No	No	No

Note: No and Yes indicate the presence of a significant difference based on non-overlapping inter-quartile ranges and 95% confidence intervals.

4.1.2 Total Kjeldahl Nitrogen (TKN)

A data matrix of the measured sediment/soil TKN levels in the 37 samples collected among the eight sampling sites and five depth increments is provided in Table 26. Figure 24 provides a boxplot of the measured sediment/soil TKN levels by sampling sites, and Figure 25 provides a boxplot of the measured sediment/soil TKN levels by depth increment. Boxplots were constructed using the MINITAB statistical software.

Table 26. Data matrix for measured sediment/soil Total Kjeldahl Nitrogen (TKN) levels.

Depth Increment (ft)	Site							
	LS-D1	**LS-D2**	**LS-D3**	**LS-D4**	**LS-D5**	**LS-D6**	**LS-D7**	**LS-D8**
0 – 2	205	1,070	613	681	181	563	143	585
2 – 4	81	235	195	110	73	290	82	499
4 – 6	159	349	68	52	121	769	75	261
6 – 8	398	136	74	64	*	652	66	440
8 – 10	223	*	120	77	*	387	65	288

* Grid cell not sampled due to bore hole collapse.

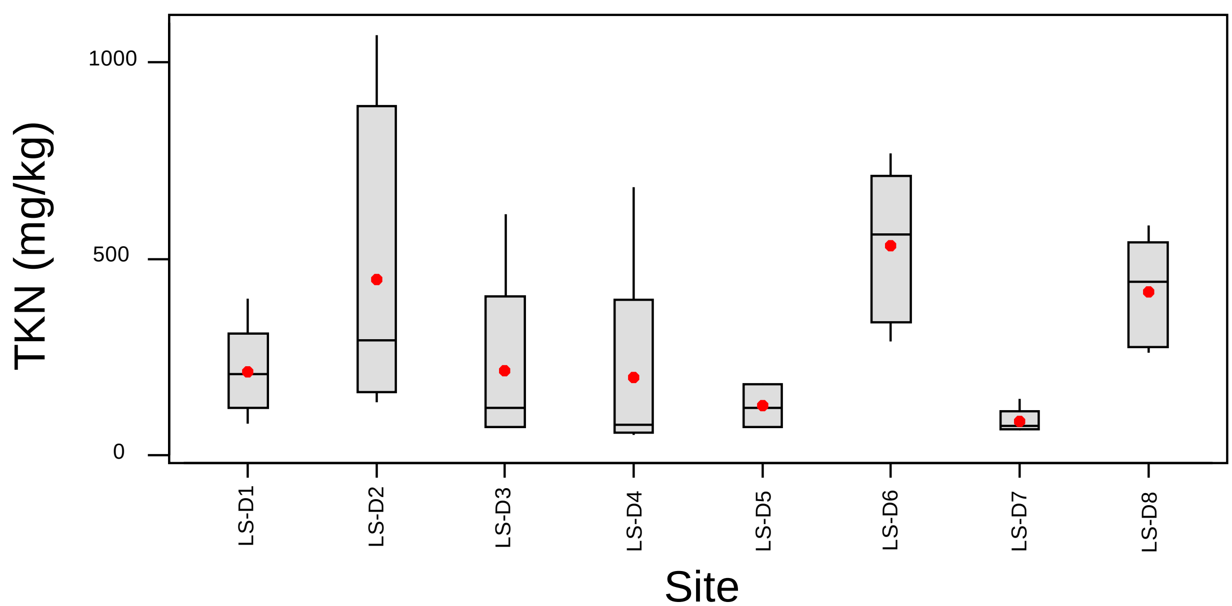


Figure 24. Boxplots of sediment/soil Total Kjeldahl Nitrogen (TKN) levels measured at the eight sampled sites. [Note: The box represents the middle 50% of the data. The line through the box represents the median. The lines (whiskers) extending from the box represent the upper and lower 25% of the data excluding outliers. Outliers, if present, are represented by asterisks (*). The red point on each plot represents the mean.]

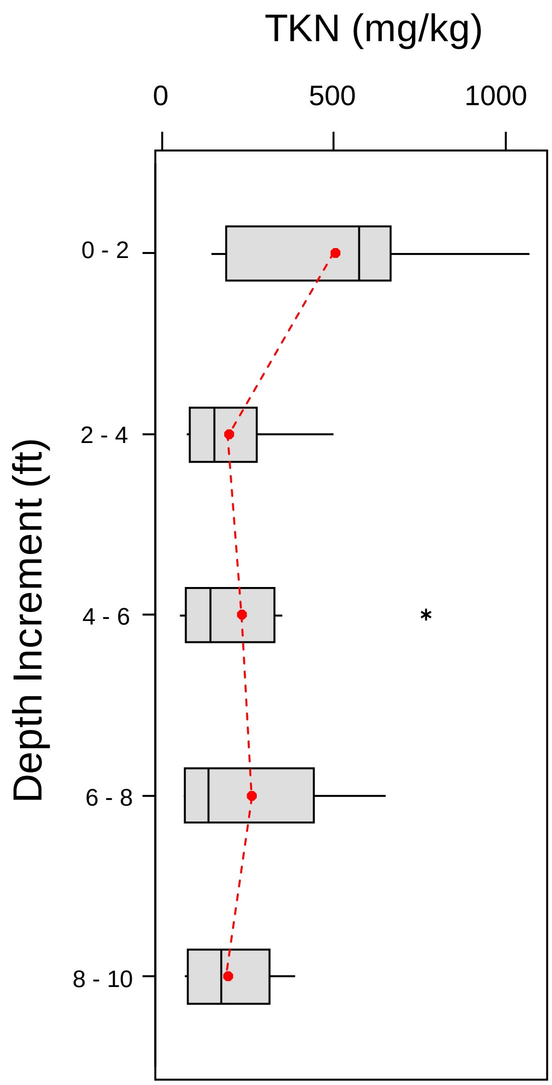


Figure 25. Boxplots of sediment/soil Total Kjeldahl Nitrogen (TKN) levels measured at the eight sampled sites by the composited depth increments. [Note: See Figure 24 for explanation of boxplot. The red dashed line represents the TKN depth profile plotted by connecting means of the depth increments.]

4.1.2.1 <u>Do TKN Levels Significantly Vary Spatially and with Depth at the Proposed Little Sioux project Area?</u>

The following hypotheses and alternative null hypotheses were tested:

$H1_o$: TKN levels measured at the eight sampled locations are significantly different.

$H1_a$: TKN levels measured at the eight sampled locations are not significantly different.

$H2_o$: TKN levels measured at different depth increments are significantly different – i.e. measured TKN levels are significantly different with depth.

$H2_a$: TKN levels measured at different depth increments are not significantly different – i.e. measured TKN levels are not significantly different with depth.

4.1.2.2 Two-Way ANOVA

A Two-Way ANOVA with the response variable as TKN and the two factors of site and depth increment was not able to be applied due to the missing depth increment data at site LS-D2 (8-10 feet) and site LS-D5 (6-8 and 8-10 feet) (Table 26).

4.1.2.3 One-Way ANOVA

A One-Way ANOVA was applied to the TKN data matrix (Table 26). The response variable is TKN and the factors evaluated separately are site and depth increment.

4.1.2.3.1 One-Way ANOVA TKN versus Site

Table 27 provides the One-Way ANOVA results for TKN versus site. Based on the premise that non-overlapping 95% confidence intervals indicate a significant difference, measured sediment/soil TKN levels at 1 of the possible 28 comparisons of sites is significantly different (Table 28).

Table 27. One-way ANOVA results: Total Kjeldahl Nitrogen versus Site

Source	DF	SS	MS	F	P
Site	7	859,049	122,721	2.66	0.029
Error	29	1,335,726	46,060		
Total	36	2,194,775			

Comparison of Sites:

```
                                                Individual 95% CIs For Mean
                                                   Based on Pooled StDev
Site          N        Mean      StDev       ------+---------+---------+---------+
LS-D1         5       213.2      117.0              (-------*------)
LS-D2         4       447.5      424.0                      (--------*--------)
LS-D3         5       214.2      228.6              (-------*------)
LS-D4         5       196.8      271.5             (-------*-------)
LS-D5         3       125.0       54.1        (---------*---------)
LS-D6         5       532.2      194.4                          (-------*-------)
LS-D7         5        86.2       32.5         (------*-------)
LS-D8         5       414.6      138.2                      (-------*------)
                                             ------+---------+---------+---------+
Pooled StDev =     214.6                             0       250       500       750
```

Table 28. Comparison of measured sediment/soil Total Kjeldahl Nitrogen levels at the eight sampled sites for significant differences.

	LS-D1	LS-D2	LS-D3	LS-D4	LS-D5	LS-D6	LS-D7
LS-D2	No						
LS-D3	No	No					
LS-D4	No	No	No				
LS-D5	No	No	No	No			
LS-D6	No	No	No	No	No		
LS-D7	No	No	No	No	No	Yes	
LS-D8	No	No	No	No	No	No	No

Note: No and Yes indicate the presence of a significant difference based on non-overlapping 95% confidence intervals.

4.1.2.3.2 One-Way ANOVA TKN versus Depth Increment

Table 29 provides the One-Way ANOVA results for TKN versus depth increment. Based on the premise that non-overlapping 95% confidence intervals indicate a significant difference, measured sediment/soil TKN levels at none of the possible 10 comparisons of depth increments are significantly different; however, the difference between depth increment 0-2 and 2-4 is nearly significantly different (Table 30).

Table 29. One-way ANOVA results: Total Kjeldahl versus Depth Increment.

Source	DF	SS	MS	F	P
Site	4	528,248	132,062	2.54	0.059
Error	32	1,666,527	52,079		
Total	36	2,194,775			

Comparison of Depth Increments:

```
                                              Individual 95% CIs For Mean
                                                  Based on Pooled StDev
Depth      N     Mean      StDev          ----------+---------+---------+------
 0-2       8     505.1     315.7                           (-------*-------)
 2-4       8     195.6     146.8           (-------*-------)
 4-6       8     231.8     240.4            (--------*-------)
 6-8       7     261.6     234.8             (--------*--------)
 8-10      6     193.3     128.6          (---------*--------)
                                          ----------+---------+---------+------
Pooled StDev =   228.2                             200       400       600
```

Table 30. Comparison of measured sediment/soil Total Kjeldahl Nitrogen levels at the five sampled depth increments for significant differences.

	0 – 2 ft	2 – 4 ft	4 -6 ft	6 – 8 ft
2 – 4 ft	No*			
4 – 6 ft	No	No		
6 – 8 ft	No	No	No	
8 – 10 ft	No	No	No	No

Note: No and Yes indicate the presence of a significant difference based on non-overlapping inter-quartile ranges and 95% confidence intervals. (Note * is nearly significantly different)

4.1.3 Nitrate-Nitrite Nitrogen

A data matrix of the measured sediment/soil nitrate-nitrite nitrogen levels in the 37 samples collected among the eight sampling sites and five depth increments is provided in Table 31. Indicative of the "soluble" nature of nitrate-nitrite nitrogen, a majority of the collected samples contained non-detectable levels of nitrate-nitrite nitrogen. Nitrate-nitrite nitrogen is readily taken up by plant growth or leached through the soil profile with water percolation. Figure 26 provides a boxplot of the measured sediment/soil nitrate-nitrite nitrogen levels by sampling sites, and Figure 27 provides a boxplot of the measured sediment/soil nitrate-nitrite levels by depth increment. Boxplots were constructed using the MINITAB statistical software. Non-detect values were set to ½ the detection limit (i.e. 0.02) to calculate statistics.

Table 31. Data matrix for measured sediment/soil nitrate-nitrite nitrogen levels.

Depth Increment (ft)	Site							
	LS-D1	**LS-D2**	**LS-D3**	**LS-D4**	**LS-D5**	**LS-D6**	**LS-D7**	**LS-D8**
0 – 2	1.1	2.3	n.d.	n.d.	n.d.	1.5	n.d.	2.6
2 – 4	1.2	n.d.	n.d.	n.d.	n.d.	1.4	n.d.	2.4
4 – 6	1.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6 – 8	n.d.	n.d.	n.d.	n.d.	*	n.d.	n.d.	n.d.
8 – 10	n.d.	*	n.d.	n.d.	*	n.d.	n.d.	n.d.

* Grid cell not sampled due to bore hole collapse.
n.d. = non-detect.

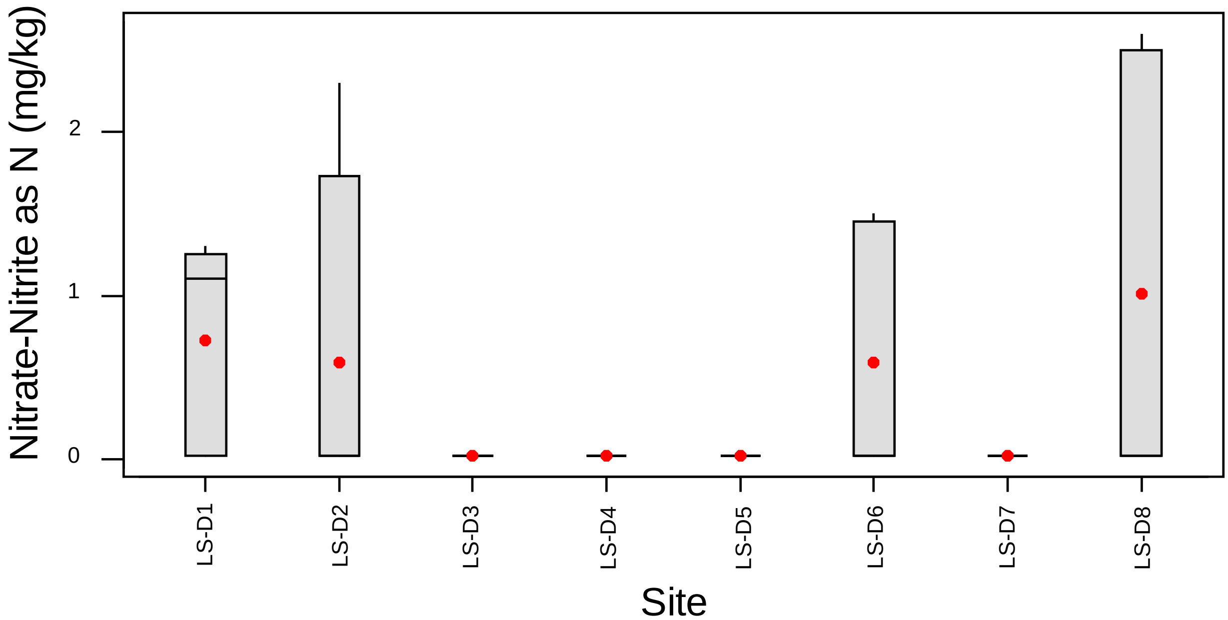


Figure 26. Boxplots of sediment/soil nitrate-nitrite as nitrogen levels measured at the eight sampling sites. [Note: The box represents the middle 50% of the data. The line through the box represents the median. The lines (whiskers) extending from the box represent the upper and lower 25% of the data excluding outliers. Outliers, if present, are represented by asterisks (*). The red point on each plot represents the mean.]

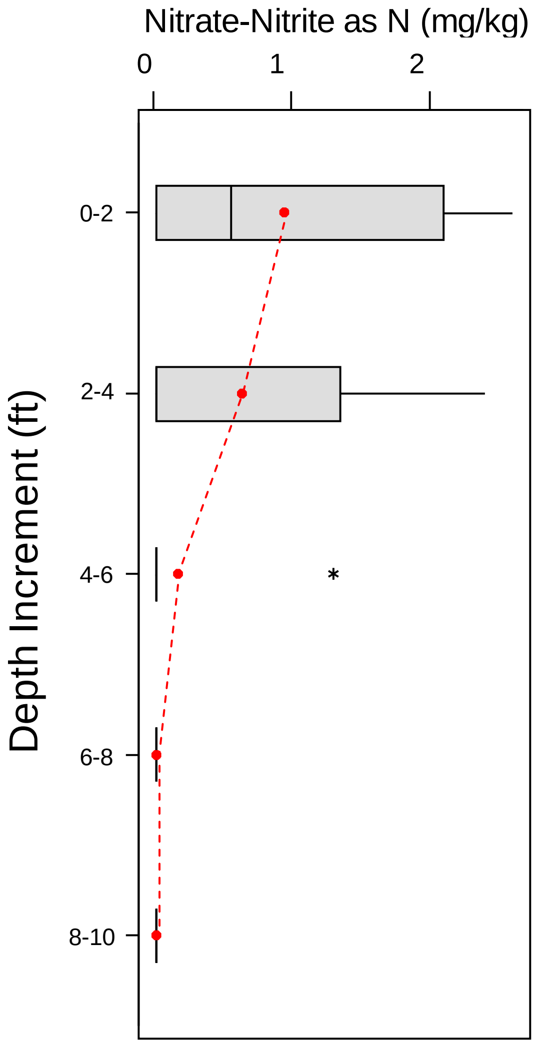


Figure 27. Boxplots of sediment/soil nitrate-nitrite nitrogen levels measured at the eight sampled sites by the composited depth increments. [Note: See Figure 26 for explanation of boxplot. The red dashed line represents the nitrate-nitrite nitrogen depth profile plotted by connecting means of the depth increments.]

4.1.3.1 <u>Do Nitrate-Nitrite Levels Significantly Vary Spatially and with Depth at the Proposed Little Sioux project Area?</u>

The following hypotheses and alternative null hypotheses were tested:

$H1_o$: Nitrate-nitrite nitrogen levels measured at the eight sampled locations are significantly different.

$H1_a$: Nitrate-nitrite nitrogen levels measured at the eight sampled locations are not significantly different.

$H2_o$: Nitrate-nitrite nitrogen levels measured at different depth increments are significantly different – i.e. measured nitrate-nitrite nitrogen levels are significantly different with depth.

$H2_a$: Nitrate-nitrite nitrogen levels measured at different depth increments are not significantly different – i.e. measured nitrate-nitrite nitrogen levels are not significantly different with depth.

4.1.3.2 <u>Two-Way ANOVA</u>

A Two-Way ANOVA with the response variable as nitrate-nitrite nitrogen and the two factors of site and depth increment was not able to be applied due to the missing depth increment data at site LS-D2 (8-10 feet) and site LS-D5 (6-8 and 8-10 feet) (Table 21).

4.1.3.3 <u>One-Way ANOVA</u>

A One-Way ANOVA was applied to the nitrate-nitrite nitrogen data matrix (Table 31). The response variable is nitrate-nitrite nitrogen and the factors evaluated separately are site and depth increment. Non-detect values were set to ½ the detection limit (i.e. 0.02) to calculate statistics.

4.1.3.3.1 One-Way ANOVA Nitrate-Nitrite Nitrogen versus Site

Table 32 provides the One-Way ANOVA results for nitrate-nitrite nitrogen versus site. Based on the premise that non-overlapping 95% confidence intervals indicate a significant difference, measured sediment/soil nitrate-nitrite nitrogen levels at none of the possible 28 comparisons of sites are significantly different (Table 33).

Table 32. One-way ANOVA results: Nitrate-Nitrite Nitrogen versus Site

Source	DF	SS	MS	F	P
Site	7	5.334	0.762	1.43	0.231
Error	29	15.449	0.533		
Total	36	20.783			

Comparison of Sites:

```
                                              Individual 95% CIs For Mean
                                                Based on Pooled StDev
Site        N     Mean      StDev        ---+---------+---------+---------+---
LS-D1       5    0.7280    0.6502                     (--------*---------)
LS-D2       4    0.5900    1.1400                  (---------*----------)
LS-D3       5    0.0200    0.0000           (--------*---------)
LS-D4       5    0.0200    0.0000           (--------*---------)
LS-D5       3    0.0200    0.0000        (-----------*------------)
LS-D6       5    0.5920    0.7840                   (--------*---------)
LS-D7       5    0.0200    0.0000           (--------*---------)
LS-D8       5    1.0120    1.3602                         (--------*---------)
                                   ---+---------+---------+---------+---
Pooled StDev =   0.7299            -0.70      0.00      0.70      1.40
```

Table 33. Comparison of measured sediment/soil nitrate-nitrite nitrogen levels at the eight sampled sites for significant differences.

	LS-D1	LS-D2	LS-D3	LS-D4	LS-D5	LS-D6	LS-D7
LS-D2	No						
LS-D3	No	No					
LS-D4	No	No	No				
LS-D5	No	No	No	No			
LS-D6	No	No	No	No	No		
LS-D7	No	No	No	No	No	No	
LS-D8	No	No	No	No	No	No	No

Note: No and Yes indicate the presence of a significant difference based on non-overlapping 95% confidence intervals.

4.1.3.3.2 One-Way ANOVA Nitrate-Nitrite Nitrogen versus Depth Increment

Table 34 provides the One-Way ANOVA results for nitrate-nitrite nitrogen versus depth increment. Based on the premise that non-overlapping 95% confidence intervals indicate a significant difference, measured sediment/soil nitrate-nitrite nitrogen levels at none of the possible 10 comparisons of depth increments are significantly different. However, the difference between depth increment 0-2 versus 6-8 and 8-10 is nearly significantly different (Table 35).

Table 34. One-way ANOVA results: Nitrate-Nitrite Nitrogen versus Depth Increment.

Source	DF	SS	MS	F	P
Site	4	5.109	1.277	2.61	0.054
Error	32	15.674	0.490		
Total	36	20.783			

Comparison of Depth Increments:

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Depth       N     Mean     StDev           ----------+---------+---------+------
 0-2        8   0.9475    1.0908                            (--------*-------)
 2-4        8   0.6375    0.9189                       (--------*-------)
 4-6        8   0.1800    0.4525                (-------*-------)
 6-8        7   0.0200    0.0000            (--------*--------)
 8-10       6   0.0200    0.0000            (--------*---------)
                                           ----------+---------+---------+------
Pooled StDev =  0.6999                        0.00      0.60      1.20
```

Table 35. Comparison of measured sediment/soil nitrate-nitrite nitrogen levels at the five sampled depth increments for significant differences.

	0 – 2 ft	2 – 4 ft	4 -6 ft	6 – 8 ft
2 – 4 ft	No			
4 – 6 ft	No	No		
6 – 8 ft	No*	No	No	
8 – 10 ft	No*	No	No	No

Note: No and Yes indicate the presence of a significant difference based on non-overlapping inter-quartile ranges and 95% confidence intervals. (Note * is nearly significantly different)

4.2 Nutrient Tonnage Associated with Suggested Disposal of Sediment/Soil Proposed for Excavation at the Little Sioux Project Area

The IDNR has suggested the following scenario for disposing of excavated material at the proposed Little Sioux project area:

- Stockpile the upper 3 feet of excavated material on one large, 24-acre "upland" area on the USACE tract.
- Excavate from 3 to 6 feet and side-cast this material in two rows along the proposed chute pilot channel (i.e. one on each side). This material may eventually be eroded into the chute and carried to the Missouri River.
- The remainder of the material to be excavated below 6 feet would be hydraulically dredged and discharged directly to the Missouri River.

The premise is that this scenario could significantly reduce the tonnage of nutrients in the Missouri River and potentially delivered to the Gulf of Mexico. To facilitate evaluating this scenario, the total tonnage of nutrients that would be present in the three layers to be excavated was estimated based on the sediment/soil conditions sampled at the Little Sioux project area.

4.2.1 Estimated Amount of Material to be Excavated at the Little Sioux Project

Table 36 gives the estimated volumes of sediment/soil material to be excavated from the three depth layers based on developed design plans for construction of SWH at the Little Sioux project area.

Table 36. Estimated amount of material to be excavated by depth layers at the proposed Little Sioux project area.

Excavation Depth Layer	Volume of Material to be Excavated
0 – 3 feet	120,000 cubic yards
3 – 6 feet	110,000 cubic yards
> 6 feet	200,000 cubic yards

4.2.2 Estimated Nutrient Conditions of the Three Proposed Depth Excavation Layers

Nutrient conditions for the three proposed sediment/soil depth excavation layers were estimated from the nutrient conditions sampled at the Little Sioux project area. The nutrient conditions for the 0-3 and 3-6 layers were estimated as a weighted average of the appropriate sampled 2-foot depth increments. Table 37 provides the estimated average nutrient conditions for the 0-3, 3-6, and greater than 6 foot depth layers.

Table. 37. Estimated average nutrient conditions of the three proposed depth excavation layers at the Little Sioux project area.

Depth Layer	Total Phosphorus (mg/kg)	Total Kjeldahl Nitrogen (mg/kg)	Nitrate-Nitrite Nitrogen (mg/kg)
0-3 feet	463	402	0.8
3-6 feet	407	220	0.3
> 6 feet	420	227	0.0

4.2.3 Estimation of the Nutrient Tonnage Associated with the Three Proposed Depth Excavation Layers

The estimated average nutrient conditions of the proposed three depth excavation layers (Table 37) were applied to the estimated amount of material to be excavated from the defined three depth layers (Table 36) to estimate the tonnage of nutrients present in the three depth layers. The conversion of sampled alluvial sediment/soil weight to volume is based on the relationship show in Table 38 that is used by the Omaha District. The mean percent sand of the sediment/soil samples collected at the eight sampled sites at the proposed Little Sioux project area ranged from 42.4 to 91.1 percent. Thus, the relationship of 95 lbs/cu-ft was used to estimate the sediment/soil weight for the proposed excavation volumes at the Little Sioux project area. Table 39 gives the estimated tonnage of nutrients present in the defined three depth layers.

Table 38. Relationship used by the Omaha District to estimate the weight of alluvial sediment based on the percent sand present.

Sediment Composition	Estimated Weight of Sediment
< 10% Sand	85 pounds/cubic foot
10 to 50% Sand	90 pounds/cubic foot
> 50% Sand	95 pounds/cubic foot

Table. 39. Estimated nutrient tonnage in the three proposed depth excavation layers at the Little Sioux project area.

Depth Layer	Cubic Yards of Excavated Material	Total Phosphorus (tons)	Total Kjeldahl Nitrogen (tons)	Nitrate-Nitrite Nitrogen (tons)
0-3 feet	120,000	71.3	61.9	0.1
3-6 feet	110,000	57.4	31.0	< 0.1
> 6 feet	200,000	107.7	58.2	< 0.1
TOTAL	**430,000**	**236.4**	**145.0**	**< 0.1**

4.2.4 Comparison of Estimated Phosphorus Tonnage of Excavated Material to Existing Conditions in the Missouri River and Gulf of Mexico

The National Research Council (NRC) of the National Academies published the report, "Missouri River Planning – Recognizing and Incorporating Sediment Management" which assessed nutrient loadings to the Missouri River and Gulf of Mexico (NRC, 2011). The report concluded that potential nitrogen loading from hydraulic dredging to construct SWH along the Missouri River was likely not a concern, but total phosphorus loadings could be a concern regarding Gulf of Mexico hypoxia. Currently, the total phosphorus load to the Gulf of Mexico is estimated to be 154,300 metric tons per year, with the contribution of the Missouri River to this total load estimated to be between 16.8% and 20% (NRC, 2011). Assuming the proposed SWH construction at the Little Sioux project area would be completed within one year, the comparison of the total phosphorus tonnage in the suggested three depth excavations at the Little Sioux project area to annual total phosphorus loadings in the Missouri River and delivered to the Gulf of Mexico are shown in Table 40. These percentages are upper bound estimates, as sediment deposition processes in the Missouri and Mississippi River channels would reduce loads delivered to the Gulf, and actual downstream deliveries would be significantly less than these values.

Table 40. Estimated total phosphorus loadings from the proposed three depth excavation layers as a percent of the existing Missouri River annual total phosphorus loadings and the annual total phosphorus load delivered to the Gulf of Mexico.

Depth Layer	Total Phosphorus (metric tons)	Percent of Annual Missouri River Total Phosphorus Load*	Percent of Annual Total Phosphorus Load Delivered to the Gulf of Mexico*
0-3 feet	64.6	0.228%	0.042%
3-6 feet	52.1	0.183%	0.034%
> 6 feet	97.7	0.344%	0.063%
TOTAL	**214.6**	**0.755%**	**0.139%**

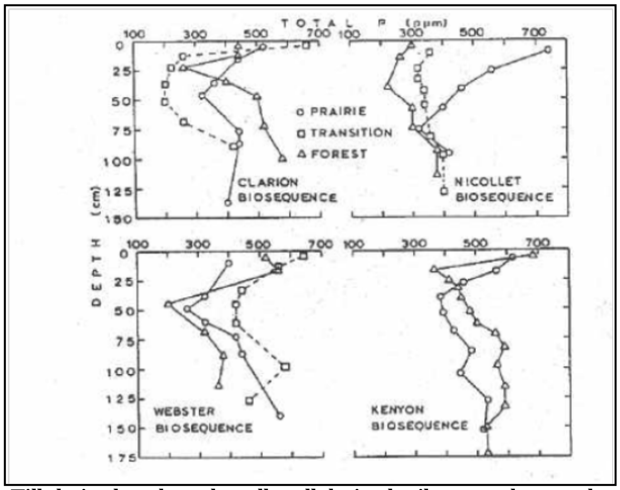
***** These percentages are upper bound estimates, as sediment deposition processes in the Missouri and Mississippi River channels would reduce loads delivered to the Gulf, and actual downstream deliveries would be significantly less than these values.

4.3 Comparison of Total Phosphorus Levels Measured at the Proposed Little Sioux Project Area to Total Phosphorus Levels Present in Off-Site Soils

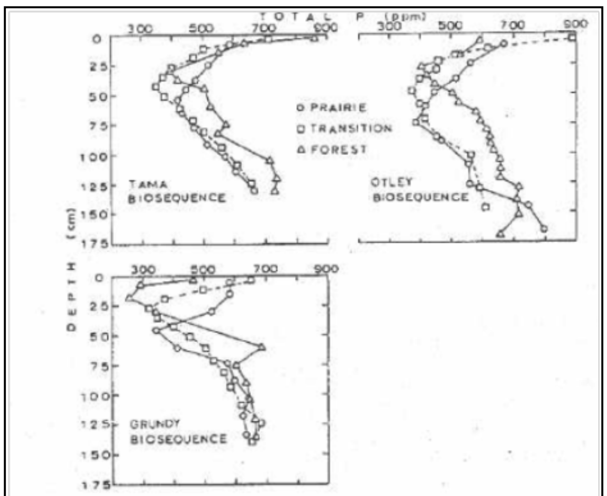
The amount of phosphorus in soil that is available for plant production (i.e. Soil Test Phosphorus – STP) is commonly measured to identify fertilization needs for agricultural production. STP is typically much lower than the total phosphorus present in the soil and potentially deliverable to streams and rivers through erosion. Recent concerns with the environmental impact of phosphorus have resulted in efforts to determine the amount of total phosphorus present in soils.

4.3.1 Phosphorus in Iowa Soils

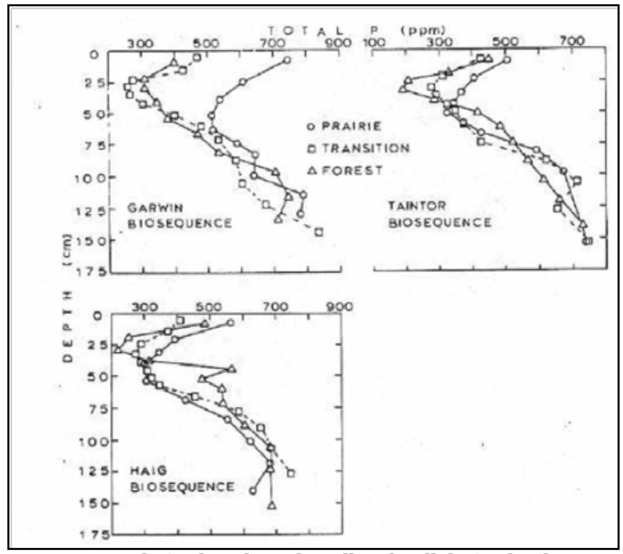
Total phosphorus levels expected in Iowa soils are identified by Fenton 1999 (Attachment 4). Biosequence effects on the genesis and resulting differences in soil phosphorus have long been recognized (Fenton, 1999). Total phosphorus in Iowa soils tends to be higher in the surface horizon, decreases to a minimum and then increases with depth within members of the biosequence (Fenton, 1999). The general trend of the distribution is similar whether the parent material is loess or glacial till (Fenton 1999). The total phosphorus depth distributions for various Iowa soil types, as reported by Fenton, 1999, are shown in Figure 26.



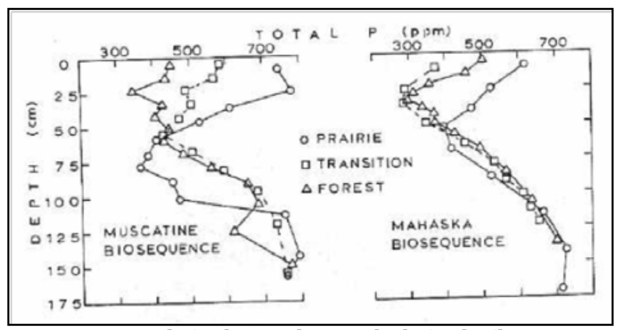
Till-derived moderately well, well drained soils, somewhat poorly, and poorly drained soils.



Loess-derived poorly drained soils.



Loess-derived moderately well and well drained soils.



Loess-derived somewhat poorly drained soils

Figure 26. Total phosphorus depth distributions for various Iowa soil types, as reported by Fenton, 1999.

4.3.2 Phosphorus in Wisconsin Soils

For nutrient management planning and other issues, the State of Wisconsin has identified the need to know the total phosphorus level present in soils within the state. The state has evaluated procedures to convert STP to total phosphorus. As part of this effort, available total phosphorus levels for soils within the State of Wisconsin were compiled and are shown in Figure 27 (Bundy and Good, 2013).

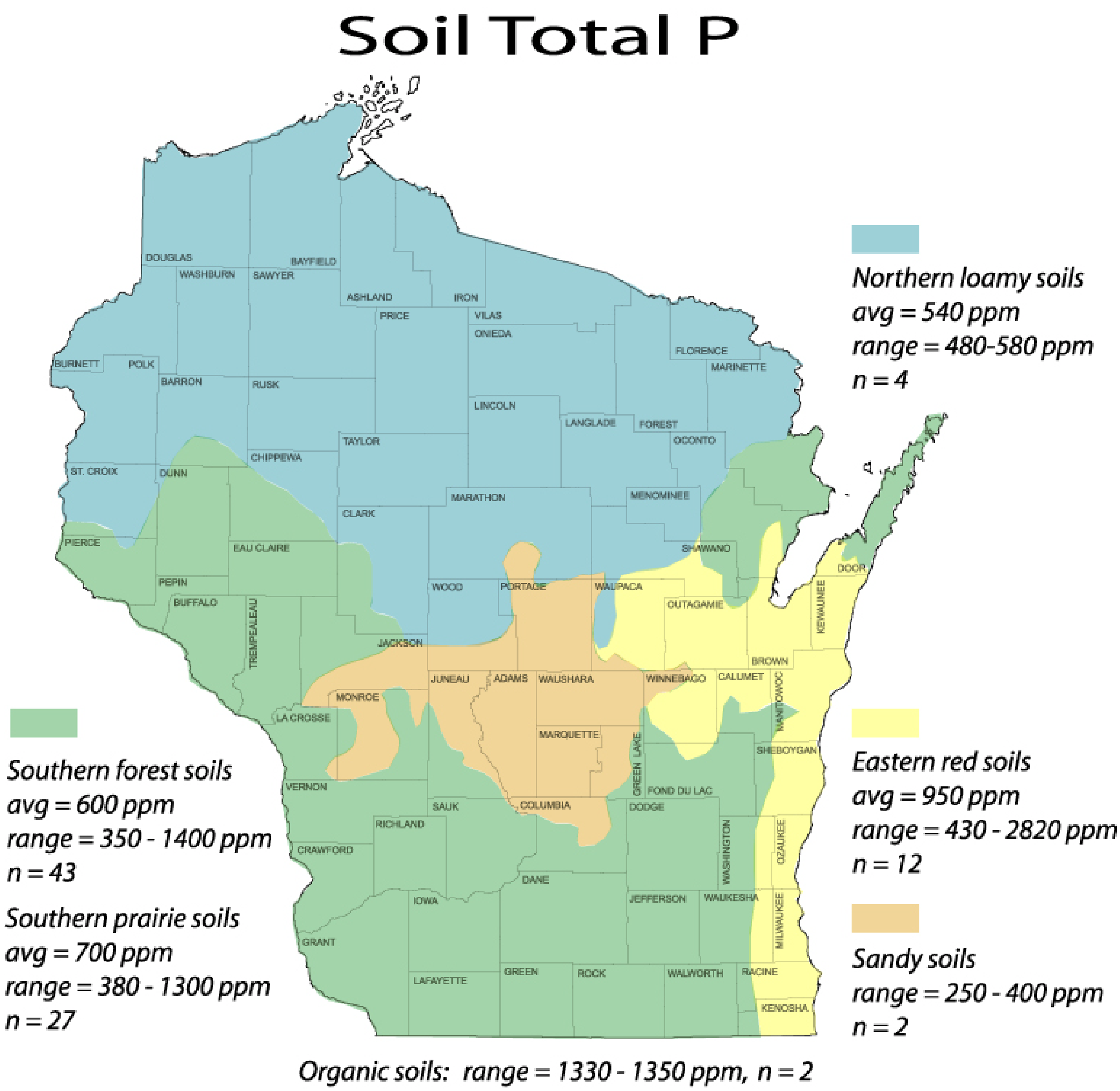


Figure 27. Total phosphorus found in Wisconsin soils.

4.3.3 Total Phosphorus Levels measured at the Proposed Little Sioux project Site

The total phosphorus levels measured in collected sediment/soil samples at the proposed Little Sioux project area are within the range of expected values based on soils and land use present at the project site. The sediment/soil total phosphorus levels measured at the proposed Little Sioux project area exhibited a similar relationship with depth as indicated for Iowa soils by Fenton, 1999. This relationship of high levels near the surface decreasing with depth and then increasing with greater depth is shown in Figure 23.

5 REFERENCES

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USACE. 2013. Water Quality Sampling Report and Factual Determinations – Results of Sediment Sampling and Elutriate Testing at the Proposed Little Sioux Bend Shallow Water Habitat Project Site. April 2013. Water Quality Unit, Water Control and Water Quality Section, Hydrological Engineering Branch, Engineering Division, Omaha District, U.S. Army Corps of Engineers.

Attachment 1

Sampling and Analysis Plan Addendum

SAMPLING AND ANALYSIS PLAN ADDENDUM

for

2013 Elutriate Sampling – Missouri River
Little Sioux Bend Project Area

Project Number: SPS-LSXBND-001

Prepared By:

Water Control and Water Quality Section
Hydrologic Engineering Branch
U.S. Army Corps of Engineers – Omaha District

September 2013

USACE – Water Quality Unit Sampling Coordinator	Date
USACE – Water Quality Unit Team Leader	Date
USACE – Chief, Water Control and Water Quality Section	Date
USACE – Chief, Sedimentation & Channel Stabilization Section	Date
USACE – (CENWO-PM-AE)	Date

ADDENDUM
(5-September-2013)

(This Addendum was prepared to collect additional sediment/soil samples to address recent concerns raised by the State of Iowa regarding the discharge of nutrients to the Missouri River via the proposed dredging discharge. It is meant to supplement the original SAP to address the need for additional information on the level of nutrients in material targeted for excavation.)

1. PROJECT DESRIPTION

1.1 BACKGROUND INFORMATION

1.1.1 Project Location

The project area is located in Harrison County, Iowa and Burt County, Nebraska along the Little Sioux Bend of the Missouri River between river miles (RM) 666 and 669 (Attachment 1).

5. DATA COLLECTION APPROACH

5.1 DATA COLLECTION DESIGN

5.1.1 Sediment/Soil Samples

Additional sediment/soil samples will be collected at eight sites (LS-D1, LS-D2, LS-D3, LS-D4, LS-D5, LS-D6, LS-D7, and LS-D8. The location of the eight sites within the project area is shown in Attachments 1 and 2. Preliminary latitude and longitude coordinates for the eight sites are given in Table 1. The “actual” location of the sampled sites will be determined with a GPS unit in the field when the samples are collected.

Table 1. Preliminary latitude and longitude coordinates for the eight locations where sediment/soil samples will be collected for analysis.

Site	Latitude	Longitude
LS-D1	41° 47’ 17.8”	96° 04’ 00.7”
LS-D2	41° 47’ 10.4”	96° 04’ 05.5”
LS-D3	41° 47’ 04.2”	96° 04’ 10.5”
LS-D4	41° 46’ 58.7”	96° 04’ 17.3”
LS-D5	41° 46’ 51.0”	96° 04’ 22.2”
LS-D6	41° 46’ 43.7”	96° 04’ 27.8”
LS-D7	41° 46’ 39.2”	96° 04’ 31.4”
LS-D8	41° 46’ 33.2”	96° 04’ 32.7”

Five depth-discrete sediment/soil samples will be collected at each of the eight sites. The five depth discrete sediment/soil samples with consist of a composted sample collected over 2-foot depth intervals from the surface to a depth of 10 feet (i.e. 0-2, 2-4, 4-6, 6-8, and 8-10 feet).

5.2 MEASUREMENT AND SAMPLING METHODS

5.2.2 Sediment/Soil Samples

Sediment/soil samples will be collected at Sites LS-S1, LS-S2, LS-S3, LS-D4, LS-D5, LS-D6, LS-D7, and LS-D8. The equipment, supplies, and procedures to be used to collect the soil samples are as follows.

5.2.2.1 Equipment and Supplies

1) Gas powered auger head
2) Stainless steel coring device
3) Gasoline
4) 1-Liter plastic bottles
5) Sample bottle labels
6) ARF
7) Field Sheets
8) GPS device
9) 5 gallon buckets
10) Pick/hammer
11) Screwdriver
12) Scrub brush

5.2.2.2 Sediment/Soil Collection Procedure

1) Select sample site and record general information (including Latitude/Longitude) on the field sheet.
2) Remove any vegetation near the proposed boring side (2-3 foot diameter circle).
3) Set out equipment near the boring site.
4) Attach the corer to the auger head, bore down and collect sample in approximately one-foot increments.
5) After each coring, detach suspend the corer over a 5-gallon plastic bucket and deposit the sample into the bucket.
6) Heavy clays may require a screwdriver, hammer and/or wooden stake or other tool to remove the sample from the corer.
7) When appropriate cores have been collected in the bucket, homogenize the contents and transfer a subsample to a 1-Liter plastic bottle. Affix completed sample label to the bottle.
8) Clean the coring device, tools and sample collection bucket between sample locations.
9) Deliver the samples and an analytical request form to the laboratory analyzing the samples.

5.4 PARAMETERS TO BE MEASURED

The following parameters that will be analyzed in the laboratory from the collected sediment/soil samples:

1) Particle Size
2) Nitrogen, Total Kjeldahl
3) Nitrogen, Nitrate-Nitrite as N
4) Phosphorus, Total

5.5 LABORATORY ANALYTICAL METHODS AND COSTS

Table 2 provides methods, detection limits, and costs for parameters to be analyzed on collected soil samples.

Table. 2. Parameters to be Analyzed on Collected Sediment/Soil Samples and Unit Costs.

Parameter	Method	Detection Limit	Analytical Cost
PHYSICAL AND AGGREGATE PROPERTIES			
Particle Size	Sieve (Minimum Sieve #200)	0.001 mm	$60.00
NUTRIENTS			
Nitrogen, Kjeldahl Total as N	EPA 351.3	0.2 mg/kg	27.50
Nitrogen, Nitrate/Nitrite Total as N	EPA 353.2	0.02 mg/kg	13.00
Phosphorus, Total	SM4500PF	0.02 mg/kg	27.00
Total Laboratory Cost for Analyzing a Soil Sample			**$127.50**

7. PROJECTED COSTS FOR FIELD COLLECTION AND LABORATORY ANALYSIS OF ELUTRIATE SAMPLES

Field Collection:

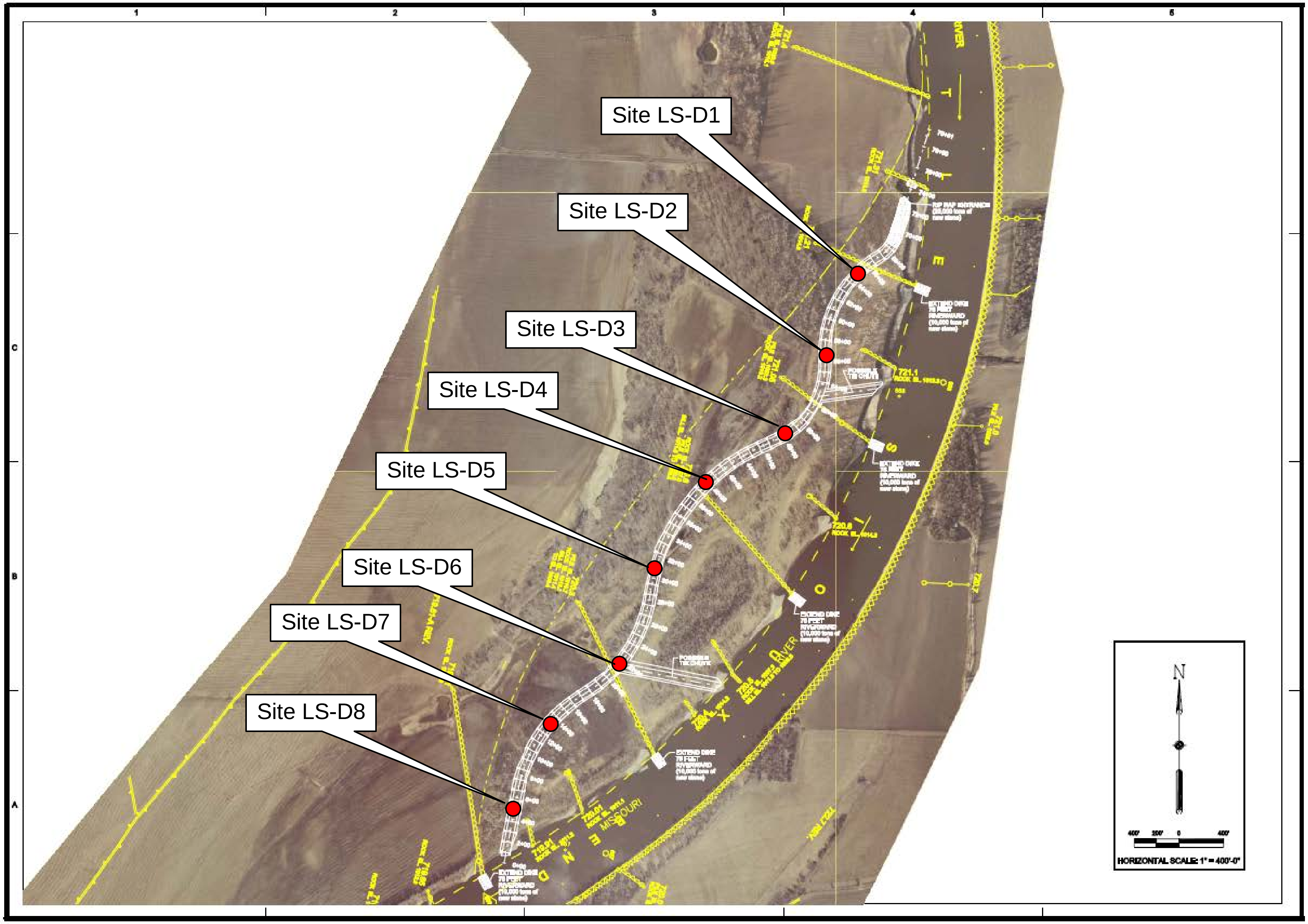
Preparation and collection of required samples 40 man hours @ $100 = $ 4,000

Laboratory Analysis (Midwest Laboratories):

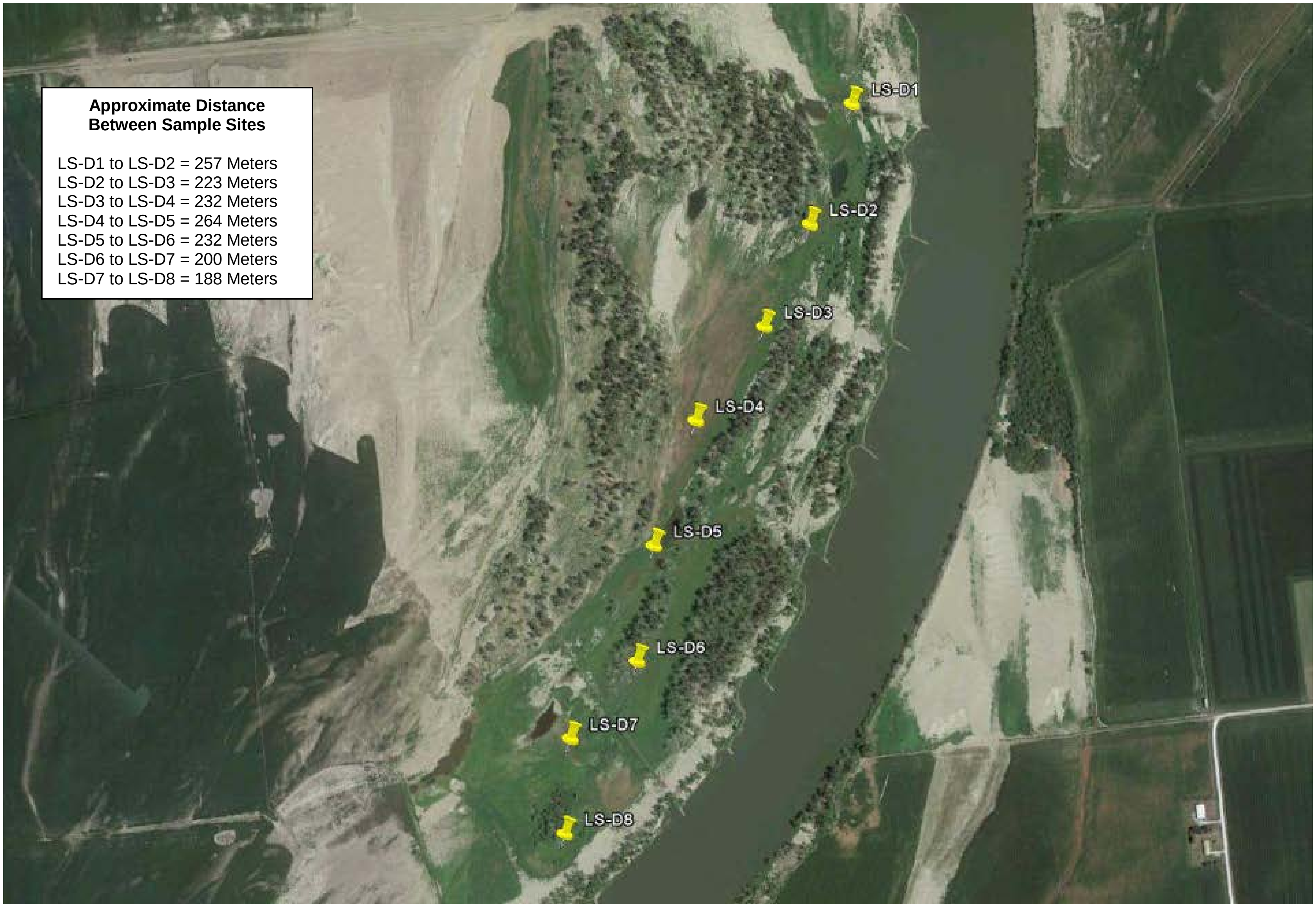
Analyzed Media	Number of Samples	Unit Cost per Sample	Total Cost
Sediment/Soil	40	$127.50	$5,100

Total Costs = $4,000.00 (Field Collection) + $5,100 (Lab Analysis) = $9,100

ATTACHMENT 1. Little Sioux Bend Project Alignment and Additional Sediment/Soil Sampling Sites.



ATTACHMENT 2. Little Sioux Bend Project Sampling Sites (Imagery Date 18-Jul-2012)**.**



ATTACHMENT 3. Field Sheet for Little Sioux Additional Sediment/Soil Sampling.

(U.S. Army Corps of Engineers – Omaha District – Water Quality Unit)

FIELD DATA SHEET

Project Name: Little Sioux Additional Sediment/Soil Sampling **Project Number:** SPS-LSXBND-001
Date: ____________________
Site Location: Little Sioux SWH Project, Missouri River
Site Numbers: LS-D1, LS-D2, LS-D3, LS-D4, LS-D5, LS-D6, LS-D7, LS-D8

Collectors: ____________________

GPS MEASUREMENTS

GPS Device Used: ____________________

Site LS-D1: Latitude: ____________________ Longitude: ____________________

Site LS-D2: Latitude: ____________________ Longitude: ____________________

Site LS-D3: Latitude: ____________________ Longitude: ____________________

Site LS-D4: Latitude: ____________________ Longitude: ____________________

Site LS-D5: Latitude: ____________________ Longitude: ____________________

Site LS-D6: Latitude: ____________________ Longitude: ____________________

Site LS-D7: Latitude: ____________________ Longitude: ____________________

Site LS-D8: Latitude: ____________________ Longitude: ____________________

SAMPLES COLLECTED

Sample Type	Sample Location	Sampled Depth (ft)					Collection Time	Sampling Method
		0-2	2-4	4-6	6-8	8-10		
Sediment/Soil	LS-D1							Composite Core
Sediment/Soil	LS-D2							Composite Core
Sediment/Soil	LS-D3							Composite Core
Sediment/Soil	LS-D4							Composite Core
Sediment/Soil	LS-D5							Composite Core
Sediment/Soil	LS-D6							Composite Core
Sediment/Soil	LS-D7							Composite Core
Sediment/Soil	LS-D8							Composite Core

COMMENTS:

Attachment 2

Particle Size Distribution Reports

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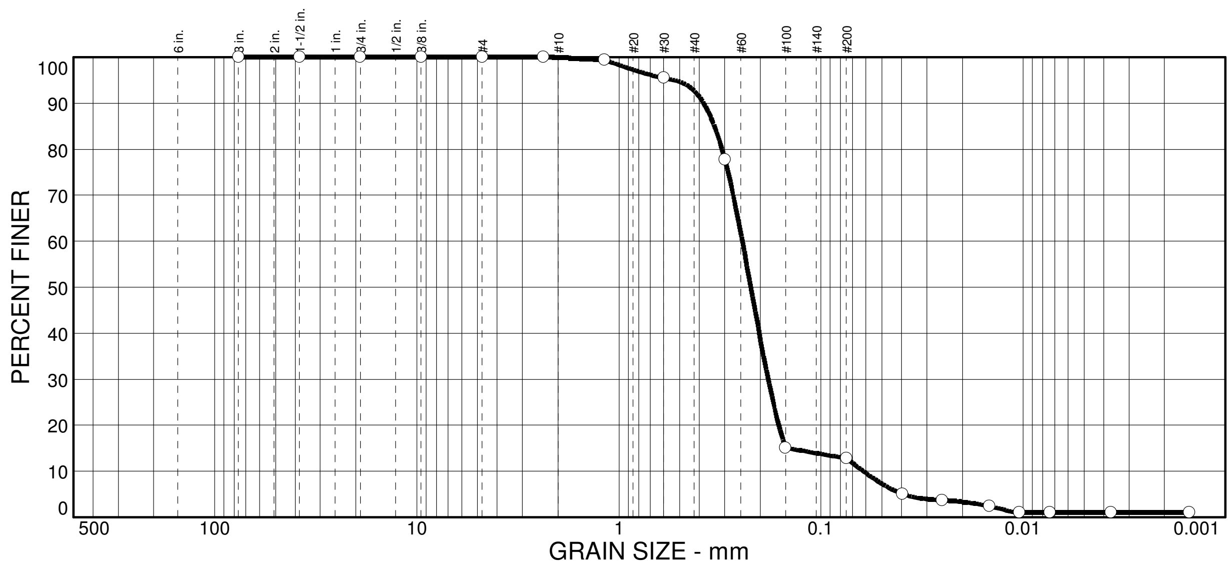
Report Number
13-301-2009

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2009
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195878 **Source of Sample:** **Date:** 10/21/13
Location: LS-D1A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.1	7.2	79.9	11.8	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.4		
#30	95.5		
#50	77.8		
#100	15.1		
#200	12.8		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.337 D_{60}= 0.246 D_{50}= 0.223
D_{30}= 0.183 D_{15}= 0.146 D_{10}= 0.0619
C_u= 3.97 C_c= 2.20

Classification

USCS= AASHTO=

Remarks

Figure

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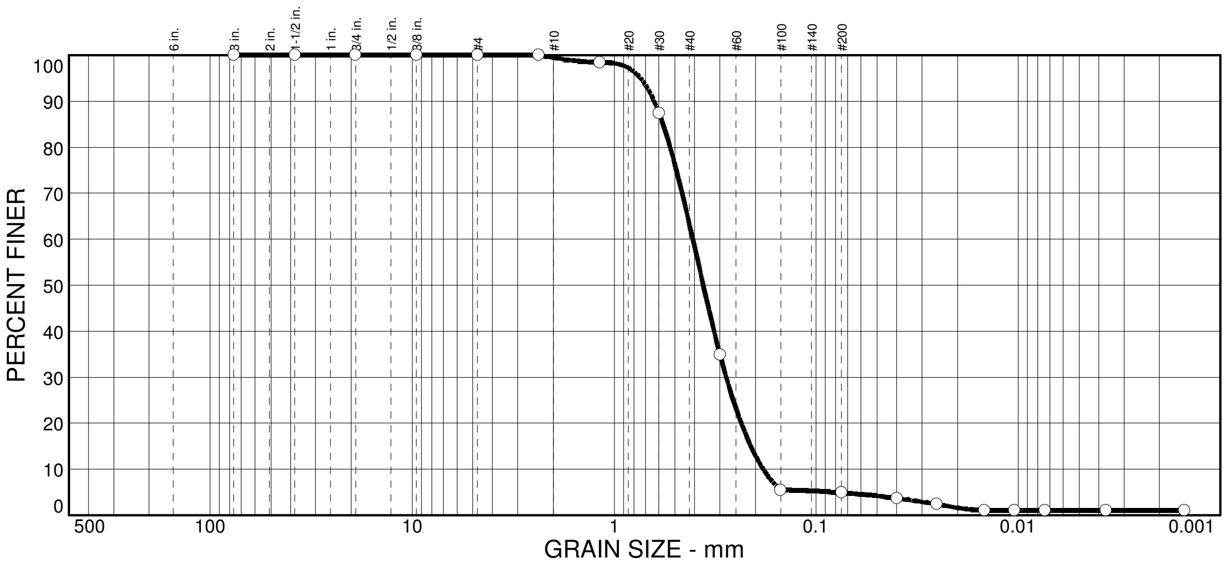
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2010

Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195879 **Source of Sample:** **Date:** 10/21/13

Location: LS-D1B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.5	36.3	58.3	3.9	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	98.4		
#30	87.4		
#50	34.9		
#100	5.5		
#200	4.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.574 D_{60}= 0.409 D_{50}= 0.363
D_{30}= 0.279 D_{15}= 0.211 D_{10}= 0.183
C_u= 2.23 C_c= 1.04

Classification

USCS= AASHTO=

Remarks

Figure

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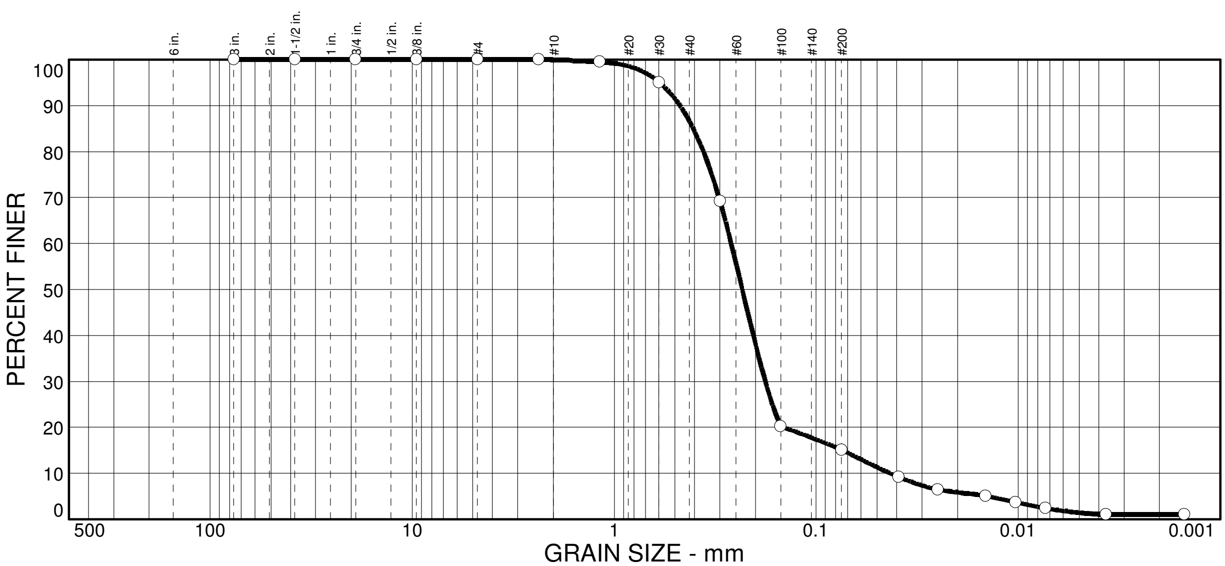
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2011
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195880 **Source of Sample:** **Date:** 10/21/13
Location: LS-D1C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.1	13.3	71.5	13.7	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.5		
#30	95.1		
#50	69.2		
#100	20.2		
#200	15.1		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.407 D_{60}= 0.264 D_{50}= 0.233
D_{30}= 0.179 D_{15}= 0.0742 D_{10}= 0.0431
C_u= 6.13 C_c= 2.81

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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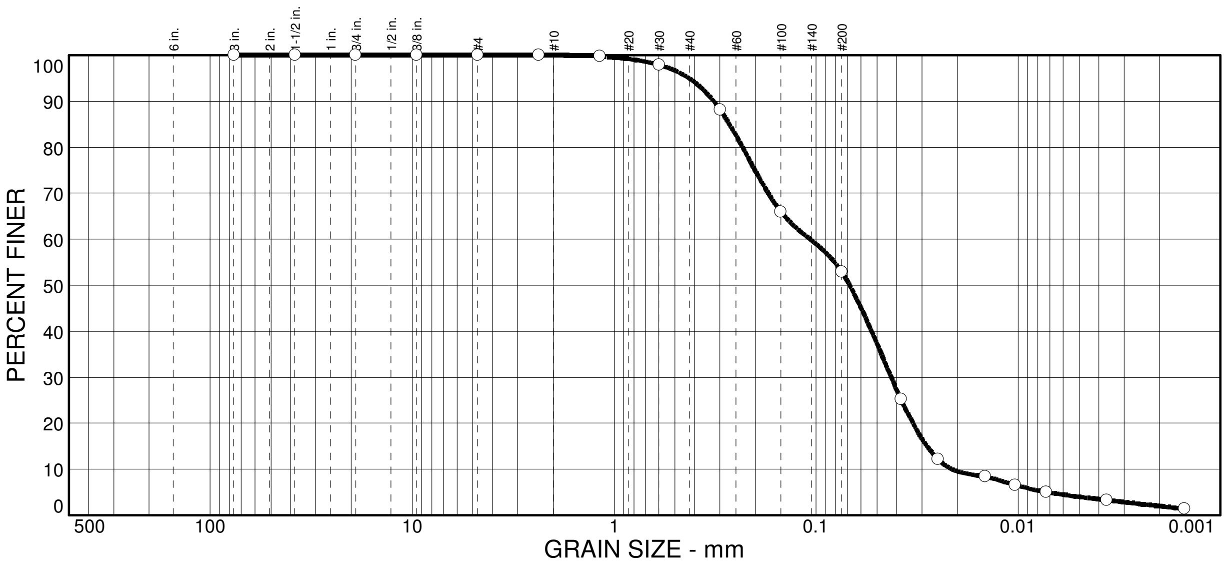
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2012
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195881 **Source of Sample:** **Date:** 10/21/13
Location: LS-D1D **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	5.0	42.1	48.9	4.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.8		
#30	97.9		
#50	88.2		
#100	66.0		
#200	52.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.269 D_{60}= 0.107 D_{50}= 0.0684
D_{30}= 0.0426 D_{15}= 0.0283 D_{10}= 0.0212
C_u= 5.06 C_c= 0.80

Classification

USCS= AASHTO=

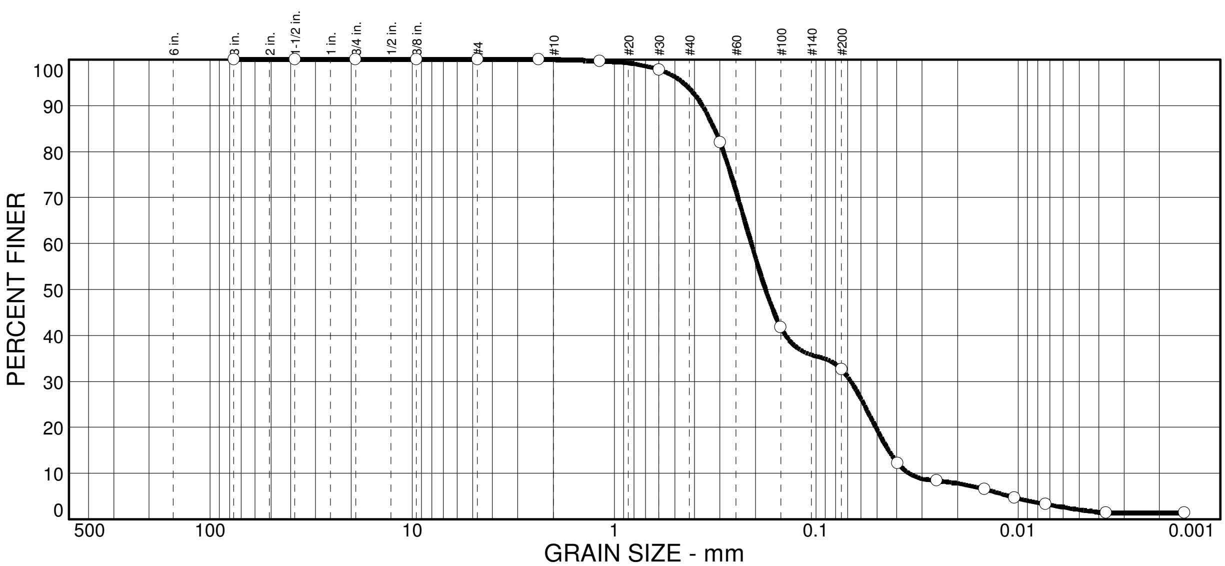
Remarks

Figure

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2013
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195882 **Source of Sample:** **Date:** 10/21/13
Location: LS-D1E **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	6.2	61.2	30.5	2.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.7		
#30	97.8		
#50	82.0		
#100	41.8		
#200	32.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.320 D_{60}= 0.210 D_{50}= 0.179
D_{30}= 0.0676 D_{15}= 0.0439 D_{10}= 0.0348
C_u= 6.04 C_c= 0.63

Classification

USCS= AASHTO=

Remarks

Figure

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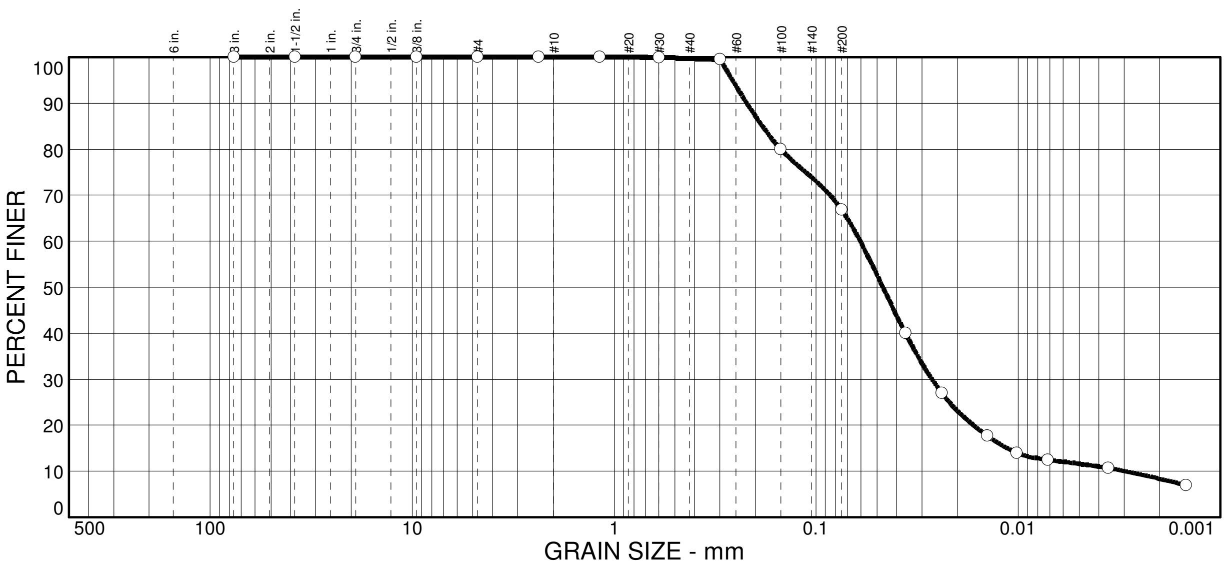
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2014

Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195883 **Source of Sample:** **Date:** 10/21/13

Location: LS-D2A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.3	32.9	55.2	11.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.9		
#50	99.5		
#100	80.0		
#200	66.8		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.185 D_{60}= 0.0606 D_{50}= 0.0468

D_{30}= 0.0268 D_{15}= 0.0114 D_{10}= 0.0029

C_u= 20.60 C_c= 4.02

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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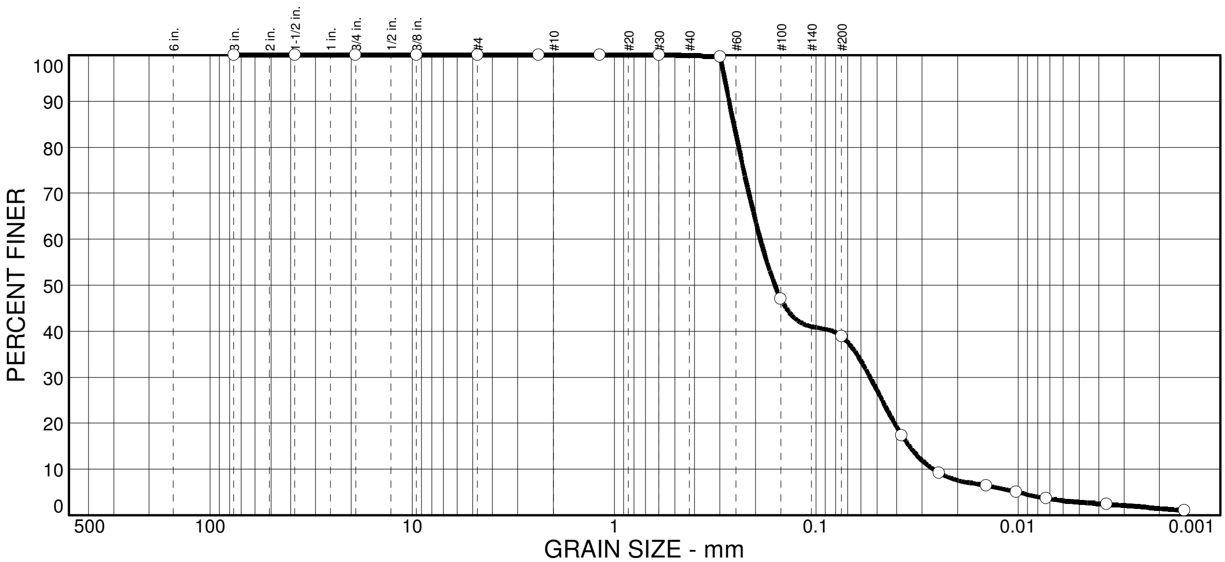
Report Number
13-301-2015

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2015
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195884 **Source of Sample:** **Date:** 10/21/13
Location: LS-D2B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.1	61.0	36.1	2.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.7		
#100	47.1		
#200	38.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.256 D_{60}= 0.190 D_{50}= 0.160
D_{30}= 0.0542 D_{15}= 0.0346 D_{10}= 0.0265
C_u= 7.16 C_c= 0.59

Classification

USCS= AASHTO=

Remarks

Figure

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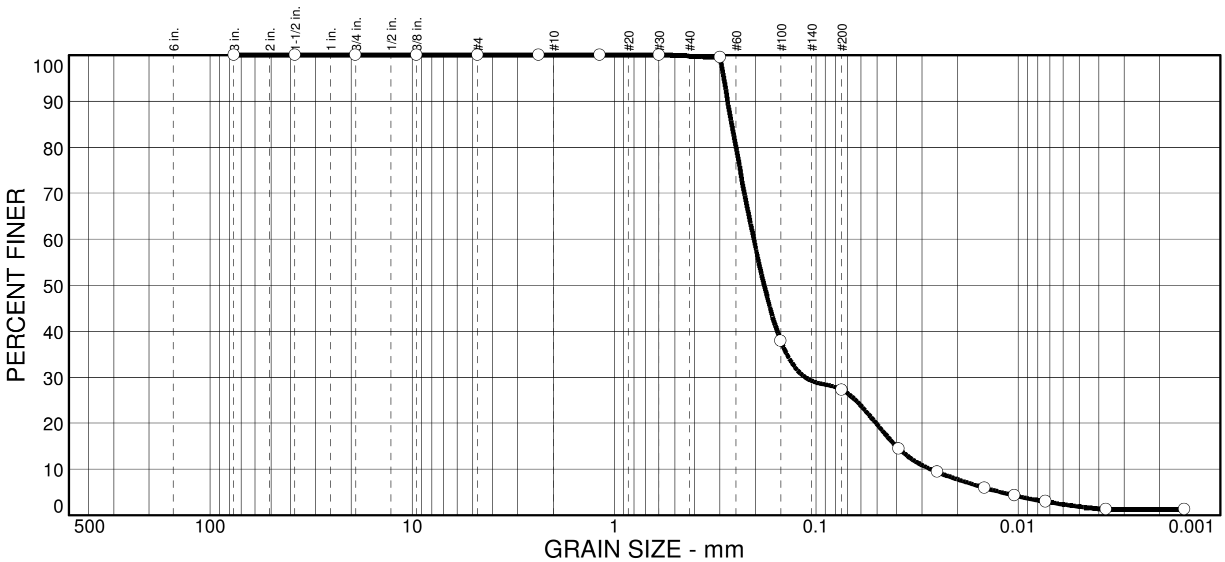
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2016
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195885 **Source of Sample:** **Date:** 10/21/13
Location: LS-D2C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.2	72.5	25.4	1.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.5		
#100	37.9		
#200	27.3		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.262 D_{60}= 0.204 D_{50}= 0.181
D_{30}= 0.114 D_{15}= 0.0402 D_{10}= 0.0272
C_u= 7.52 C_c= 2.33

Classification

USCS= AASHTO=

Remarks

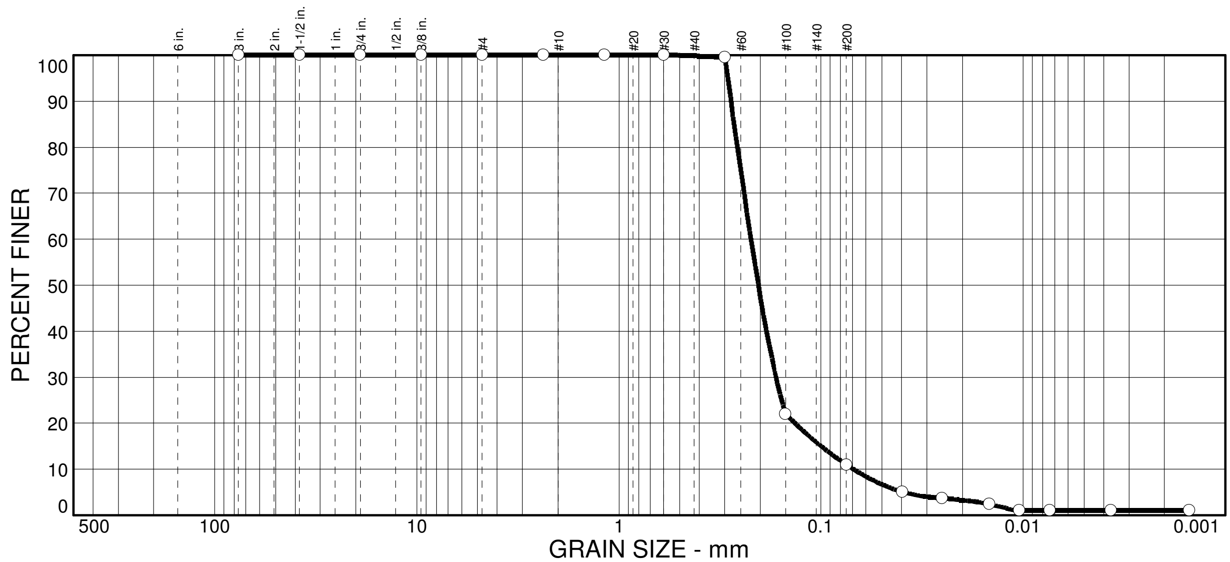
* (no specification provided)

Figure

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2017
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195886 **Source of Sample:** **Date:** 10/21/13
Location: LS-D2D **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.1	88.9	10.0	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.6		
#100	22.0		
#200	11.0		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.270 D_{60}= 0.223 D_{50}= 0.205
D_{30}= 0.167 D_{15}= 0.100 D_{10}= 0.0692
C_u= 3.22 C_c= 1.82

Classification

USCS= AASHTO=

Remarks

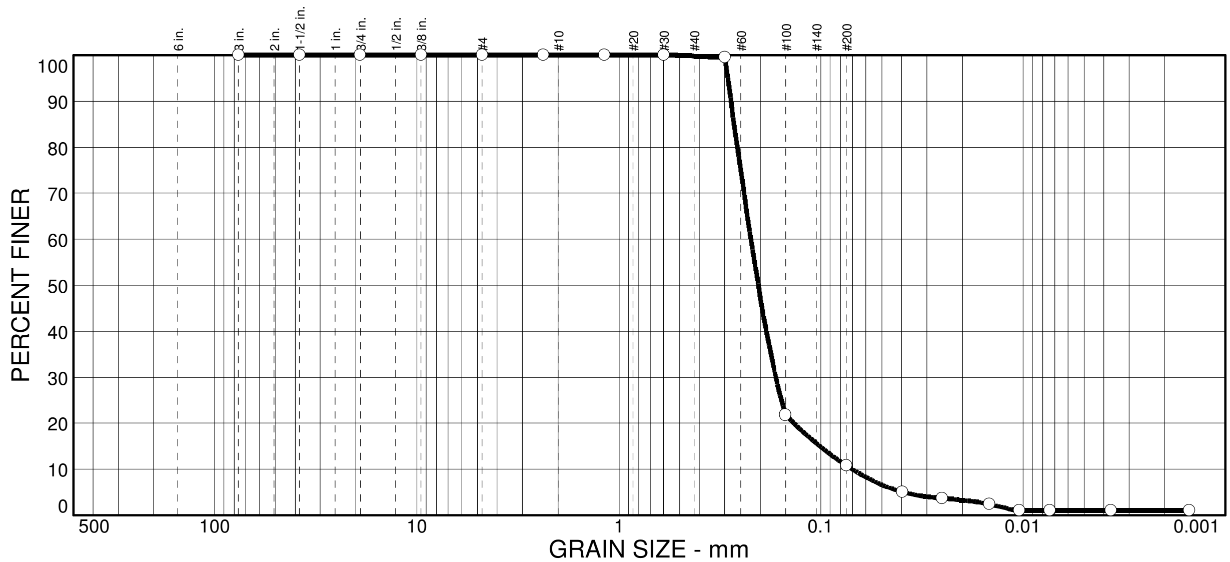
* (no specification provided)

Figure

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2017
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195886 DUP **Source of Sample:** **Date:** 10/21/13
Location: LS-D2D DUP **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.2	89.0	9.8	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.5		
#100	21.8		
#200	10.8		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.270 D_{60}= 0.223 D_{50}= 0.205
D_{30}= 0.168 D_{15}= 0.102 D_{10}= 0.0702
C_u= 3.17 C_c= 1.80

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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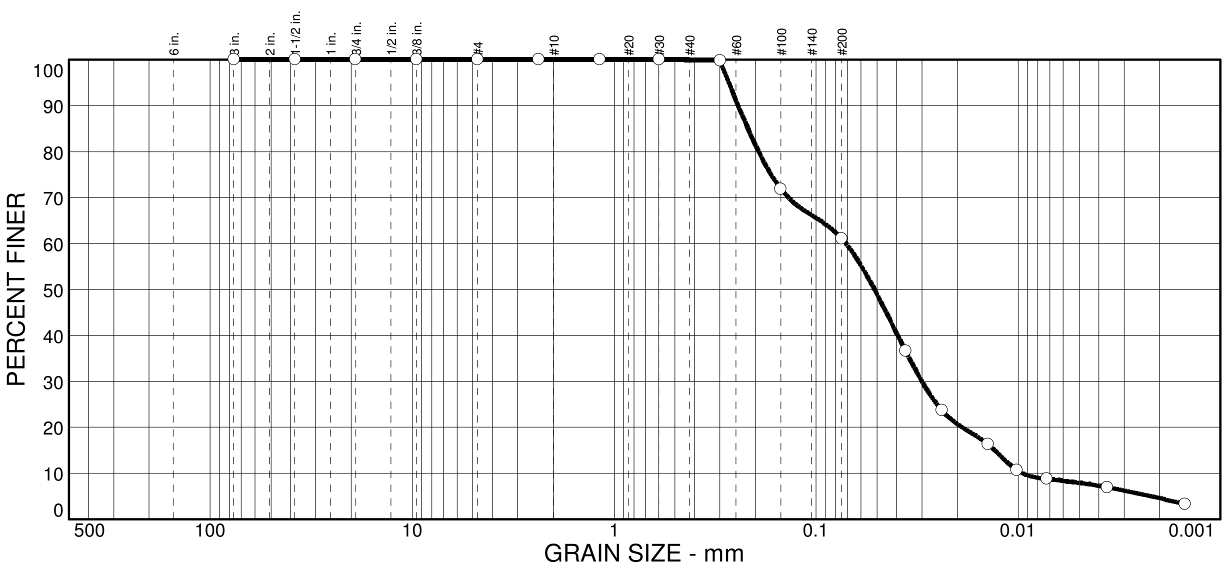
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2018
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195887 **Source of Sample:** **Date:** 10/21/13
Location: LS-D3A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.1	38.8	53.2	7.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.8		
#100	71.9		
#200	61.1		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.218 D_{60}= 0.0714 D_{50}= 0.0516
D_{30}= 0.0300 D_{15}= 0.0131 D_{10}= 0.0095
C_u= 7.51 C_c= 1.33

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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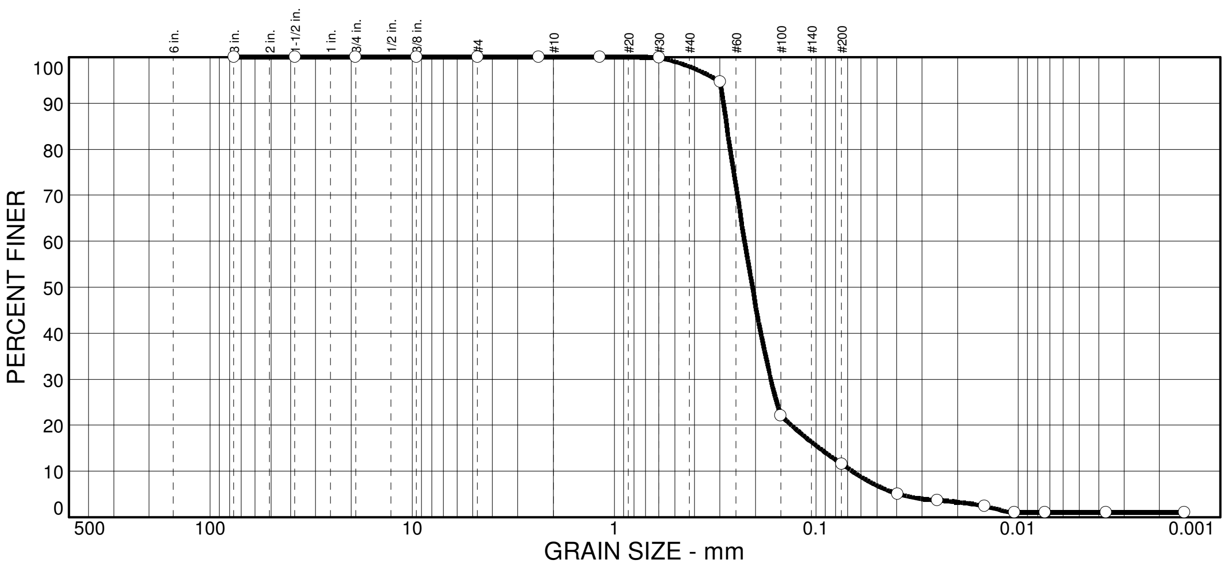
Report Number
13-301-2019

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2019
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195888 **Source of Sample:** **Date:** 10/21/13
Location: LS-D3B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	2.0	86.4	10.6	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.9		
#50	94.7		
#100	22.1		
#200	11.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.278 D_{60}= 0.227 D_{50}= 0.207
D_{30}= 0.168 D_{15}= 0.0965 D_{10}= 0.0664
C_u= 3.41 C_c= 1.88

Classification

USCS= AASHTO=

Remarks

Figure

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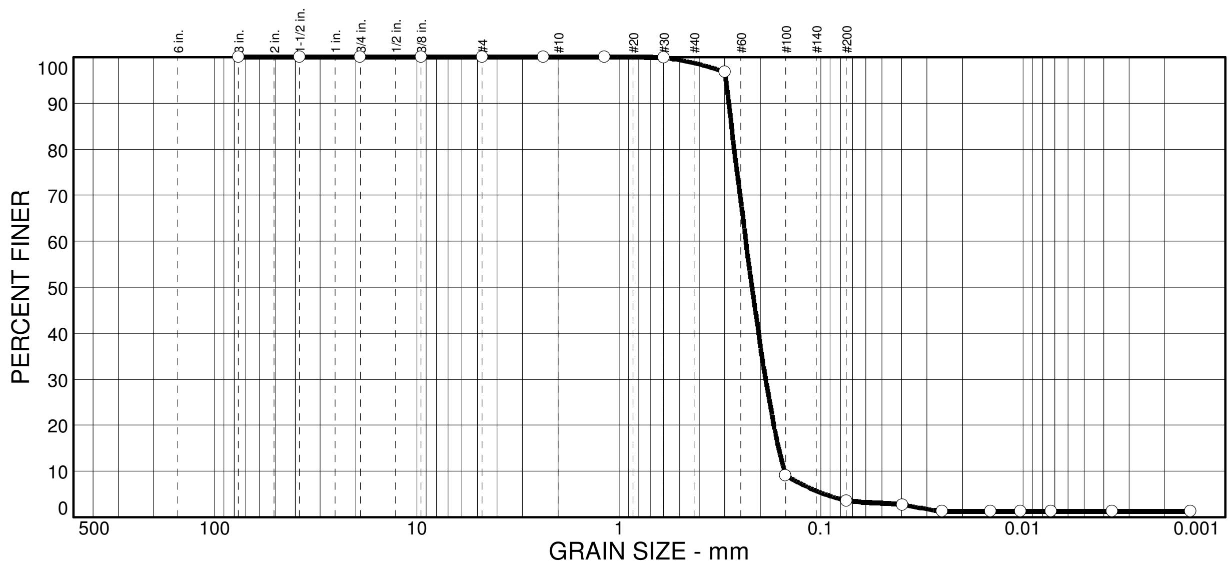
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2020
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195889 **Source of Sample:** **Date:** 10/21/13
Location: LS-D3C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	1.3	95.1	2.3	1.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.9		
#50	96.8		
#100	9.1		
#200	3.6		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.278 D_{60}= 0.236 D_{50}= 0.220
D_{30}= 0.188 D_{15}= 0.162 D_{10}= 0.152
C_u= 1.55 C_c= 0.99

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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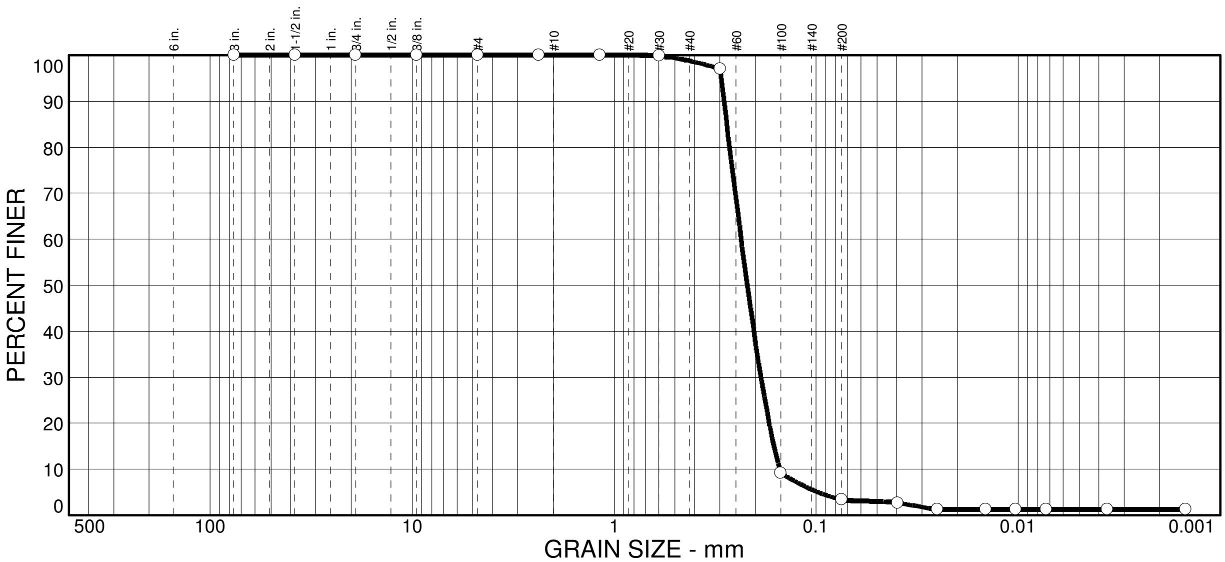
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2021
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195890 **Source of Sample:** **Date:** 10/21/13
Location: LS-D3D **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	1.2	95.4	2.1	1.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.9		
#50	97.0		
#100	9.2		
#200	3.4		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.278 D_{60}= 0.236 D_{50}= 0.220
D_{30}= 0.188 D_{15}= 0.162 D_{10}= 0.152
C_u= 1.55 C_c= 0.99

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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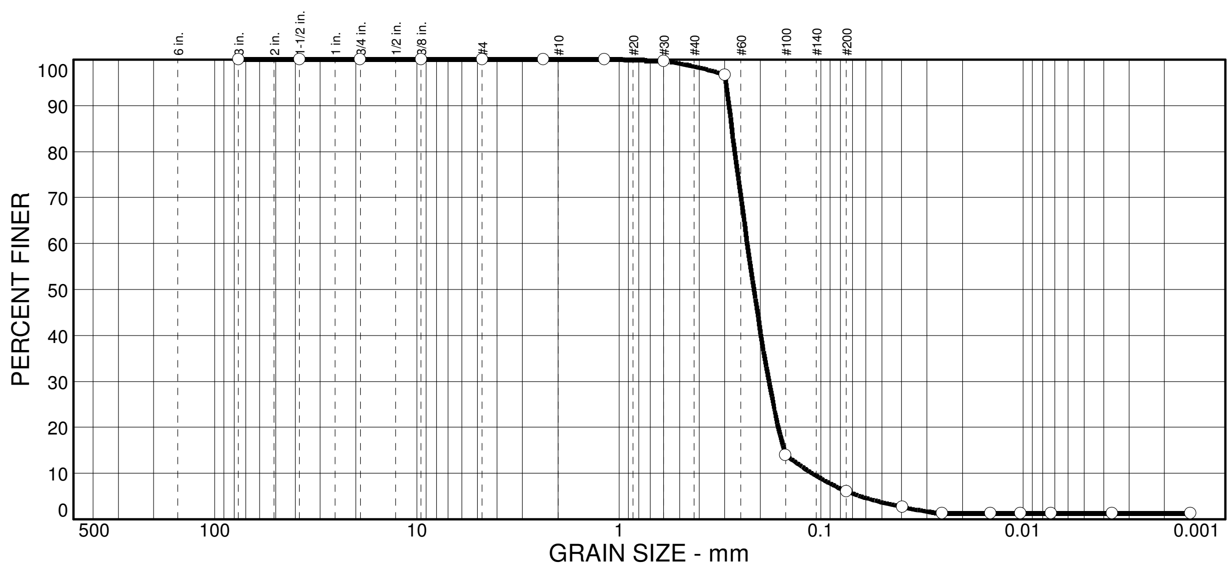
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2023
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195891 **Source of Sample:** **Date:** 10/21/13
Location: LS-D3E **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	1.5	92.4	4.8	1.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.7		
#50	96.7		
#100	14.0		
#200	6.1		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.277 D_{60}= 0.232 D_{50}= 0.215
D_{30}= 0.182 D_{15}= 0.152 D_{10}= 0.111
C_u= 2.10 C_c= 1.28

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

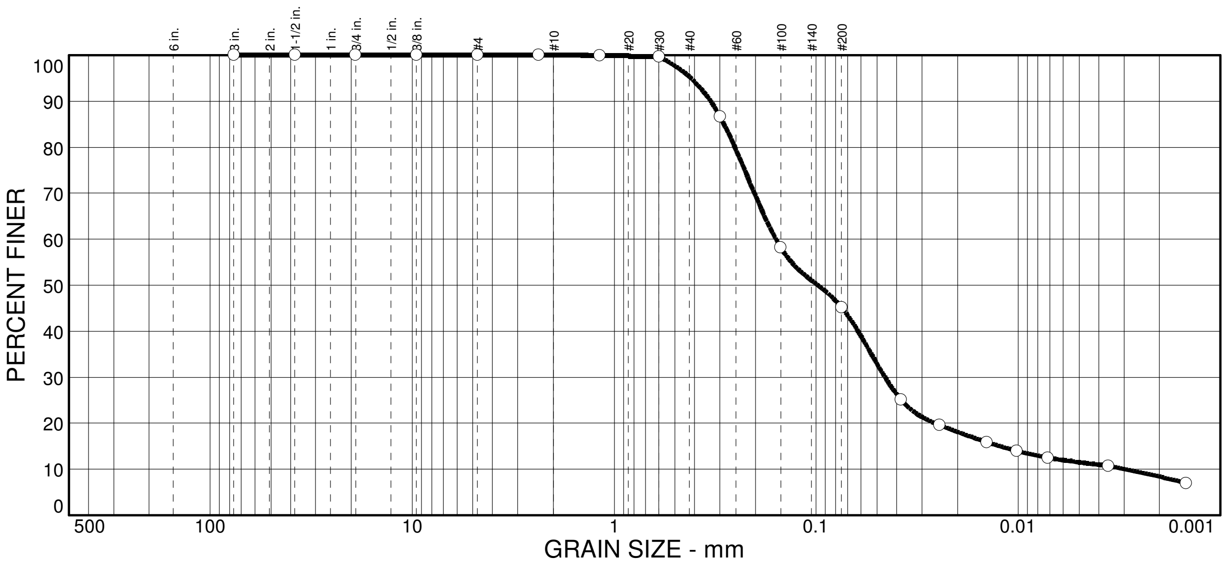
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2024

Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195892 **Source of Sample:** **Date:** 10/21/13

Location: LS-D4A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	4.7	50.1	33.7	11.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.9		
#30	99.7		
#50	86.7		
#100	58.2		
#200	45.2		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.286 D_{60}= 0.159 D_{50}= 0.0984

D_{30}= 0.0457 D_{15}= 0.0123 D_{10}= 0.0029

C_u= 54.43 C_c= 4.53

Classification

USCS= AASHTO=

Remarks

Figure

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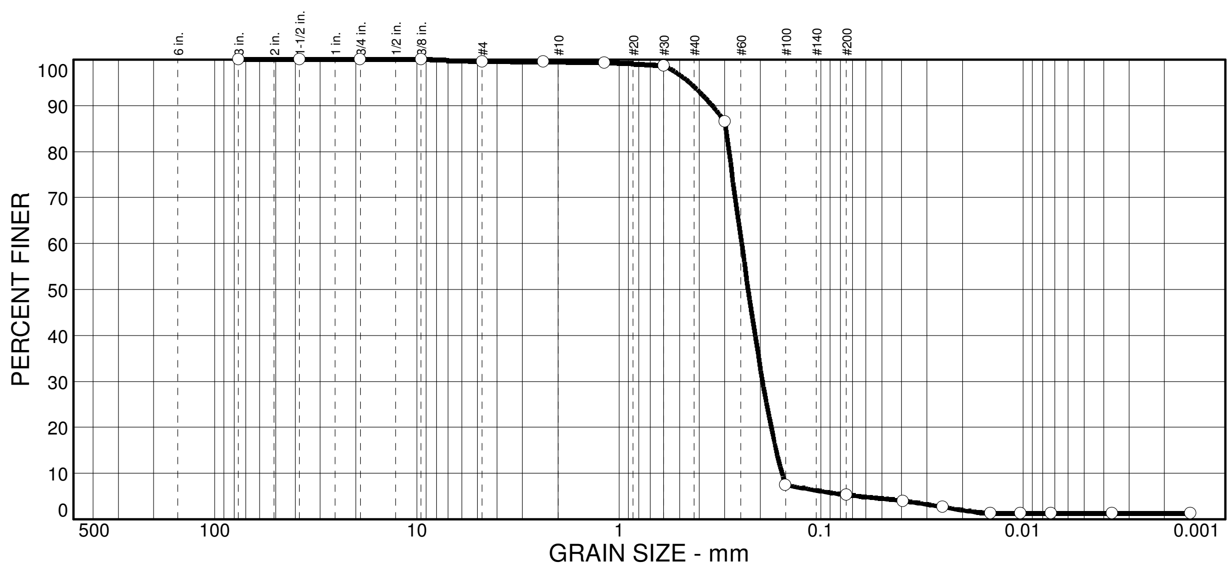
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2025
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195893 **Source of Sample:** **Date:** 10/21/13
Location: LS-D4B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.4	0.1	5.4	88.8	4.0	1.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	99.6		
#8	99.5		
#16	99.3		
#30	98.7		
#50	86.5		
#100	7.5		
#200	5.3		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.297 D_{60}= 0.248 D_{50}= 0.230
D_{30}= 0.195 D_{15}= 0.167 D_{10}= 0.156
C_u= 1.59 C_c= 0.98

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

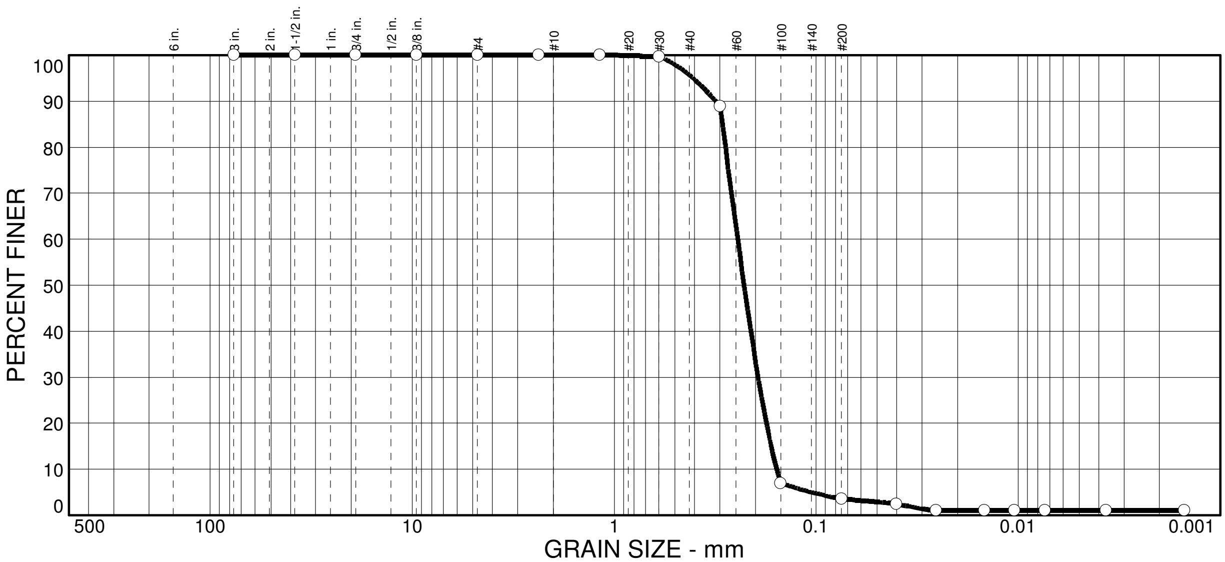
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2026

Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195894 **Source of Sample:** **Date:** 10/21/13

Location: LS-D4C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	4.3	92.1	2.6	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.7		
#50	88.9		
#100	7.0		
#200	3.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.292 D_{60}= 0.245 D_{50}= 0.228
D_{30}= 0.194 D_{15}= 0.167 D_{10}= 0.157
C_u= 1.56 C_c= 0.98

Classification

USCS= AASHTO=

Remarks

Figure

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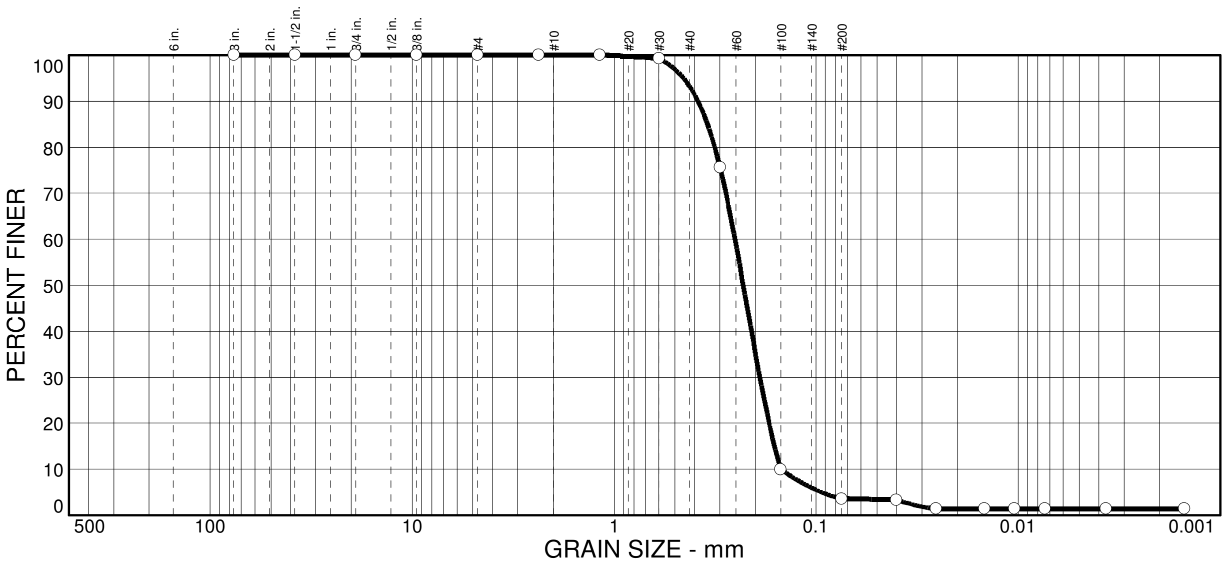
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2027
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195895 **Source of Sample:** **Date:** 10/21/13
Location: LS-D4D **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	6.7	89.7	2.2	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.3		
#50	75.6		
#100	10.0		
#200	3.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.346 D_{60}= 0.253 D_{50}= 0.230
D_{30}= 0.191 D_{15}= 0.161 D_{10}= 0.150
C_u= 1.69 C_c= 0.96

Classification

USCS= AASHTO=

Remarks

Figure

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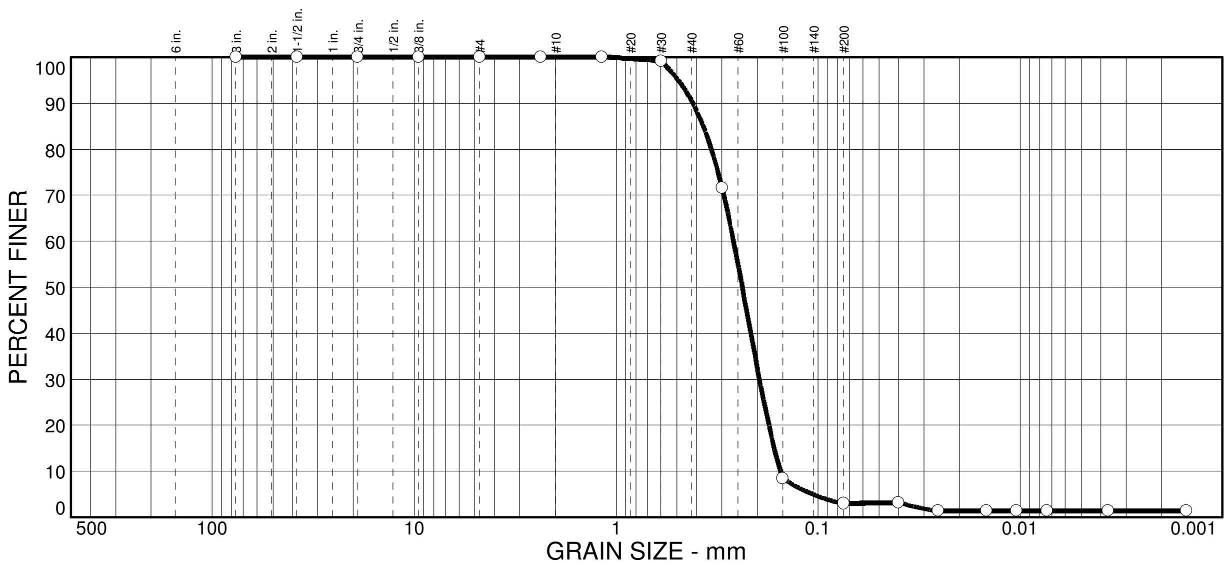
Report Number
13-301-2027

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2027
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195895 DUP **Source of Sample:** **Date:** 10/21/13
Location: LS-D4D DUP **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	9.4	87.6	1.6	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.2		
#50	71.6		
#100	8.4		
#200	3.0		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.371 D_{60}= 0.263 D_{50}= 0.238
D_{30}= 0.196 D_{15}= 0.165 D_{10}= 0.154
C_u= 1.71 C_c= 0.95

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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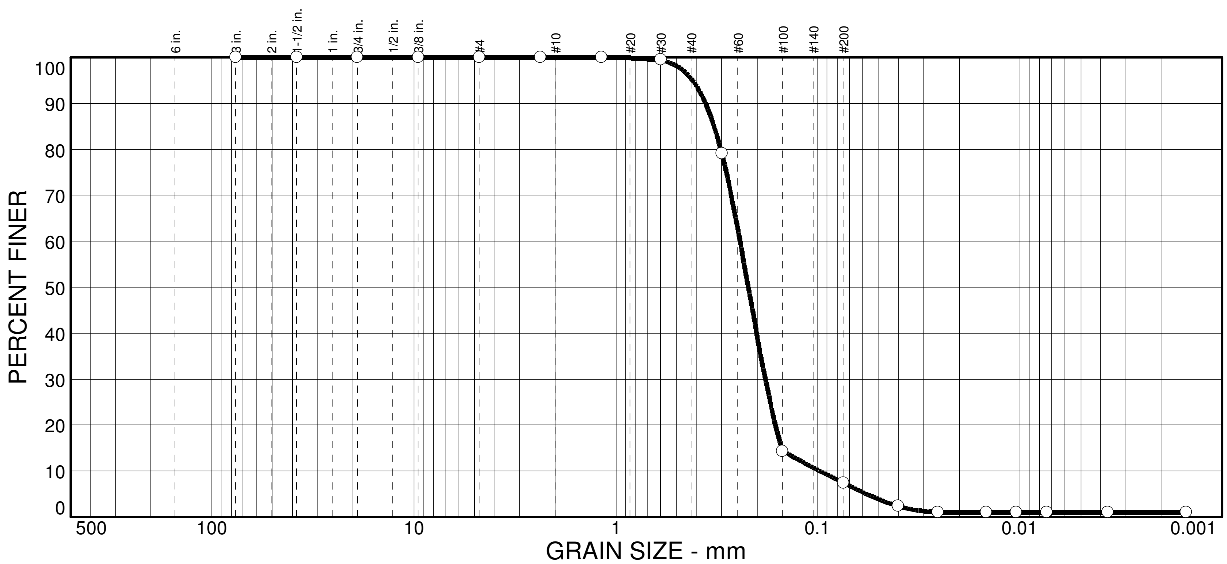
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2028
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195896 **Source of Sample:** **Date:** 10/21/13
Location: LS-D4E **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	4.6	87.9	6.5	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.5		
#50	79.1		
#100	14.4		
#200	7.5		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.327 D_{60}= 0.244 D_{50}= 0.222
D_{30}= 0.183 D_{15}= 0.151 D_{10}= 0.0979
C_u= 2.49 C_c= 1.40

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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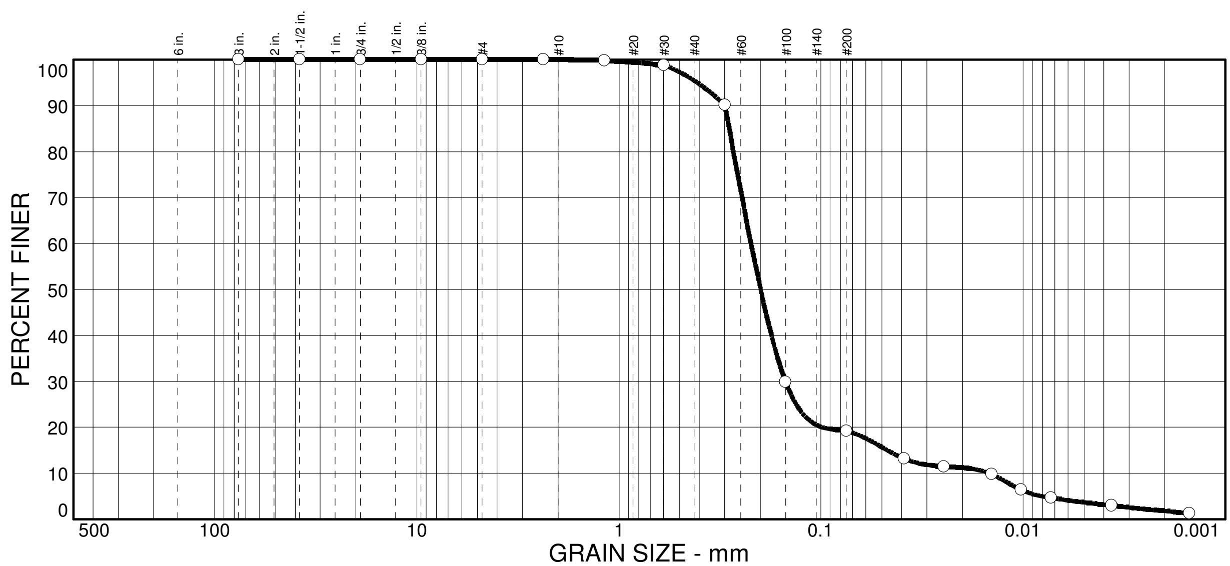
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2029
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195897 **Source of Sample:** **Date:** 10/21/13
Location: LS-D5A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	4.5	76.3	15.5	3.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.8		
#30	98.8		
#50	90.1		
#100	29.9		
#200	19.2		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.285 D_{60}= 0.223 D_{50}= 0.200
D_{30}= 0.150 D_{15}= 0.0471 D_{10}= 0.0147
C_u= 15.12 C_c= 6.89

Classification

USCS= AASHTO=

Remarks

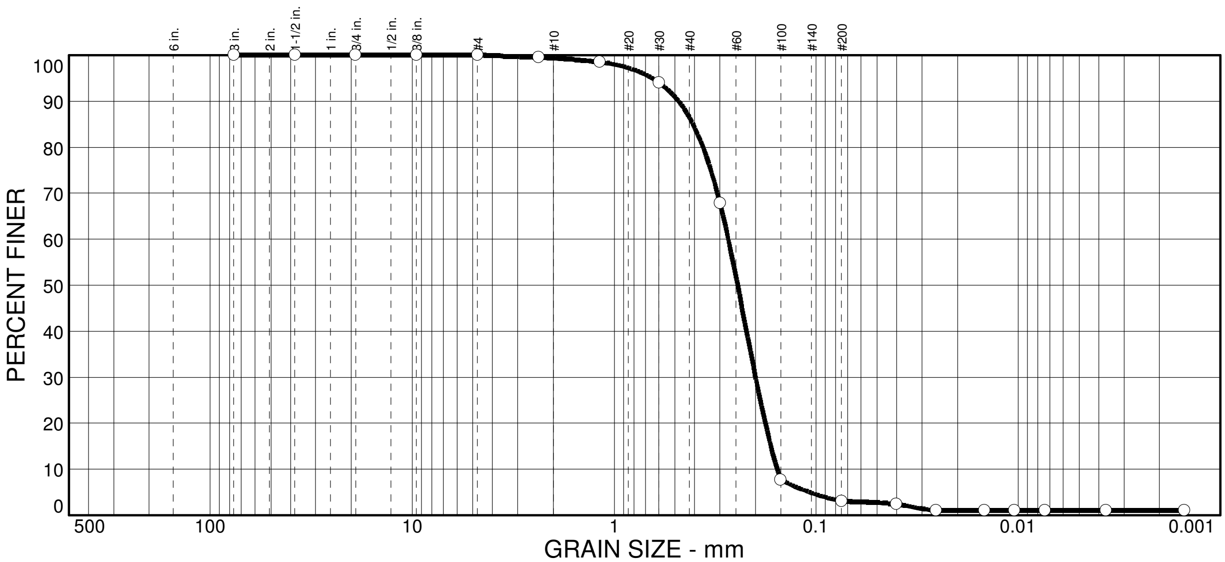
* (no specification provided)

Figure

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2030
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195898 **Source of Sample:** **Date:** 10/21/13
Location: LS-D5B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.6	12.9	83.4	2.1	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	99.5		
#16	98.5		
#30	94.0		
#50	67.8		
#100	7.7		
#200	3.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.408 D_{60}= 0.273 D_{50}= 0.245
D_{30}= 0.200 D_{15}= 0.168 D_{10}= 0.156
C_u= 1.75 C_c= 0.94

Classification

USCS= AASHTO=

Remarks

Figure

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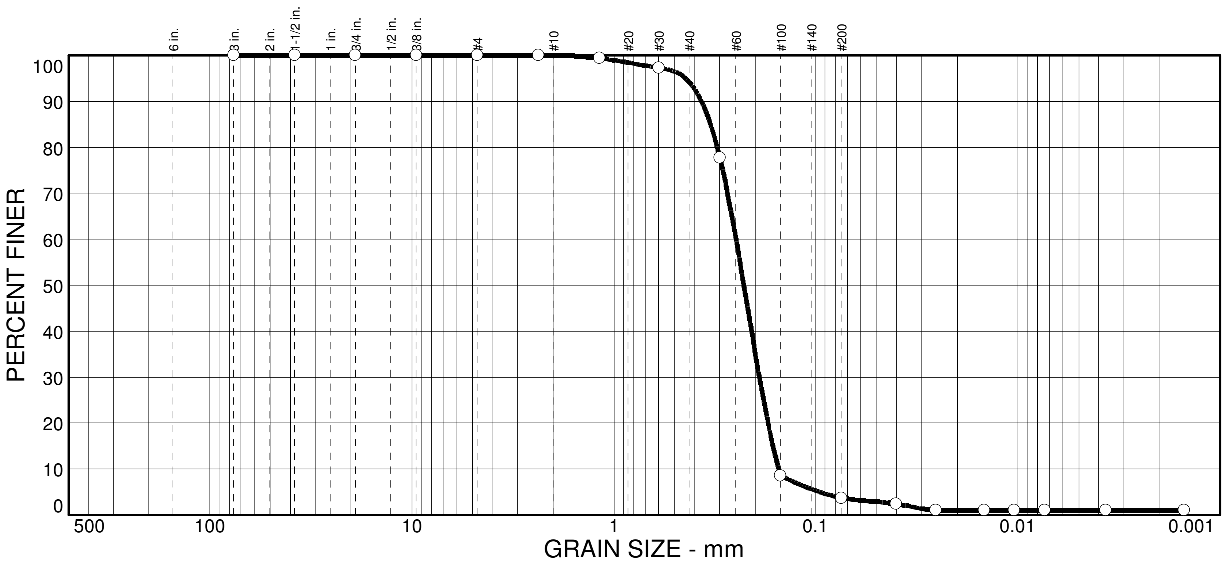
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2031
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195899 **Source of Sample:** **Date:** 10/21/13
Location: LS-D5C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	5.7	90.6	2.7	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.4		
#30	97.3		
#50	77.8		
#100	8.6		
#200	3.7		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.333 D_{60}= 0.249 D_{50}= 0.228
D_{30}= 0.191 D_{15}= 0.164 D_{10}= 0.153
C_u= 1.63 C_c= 0.95

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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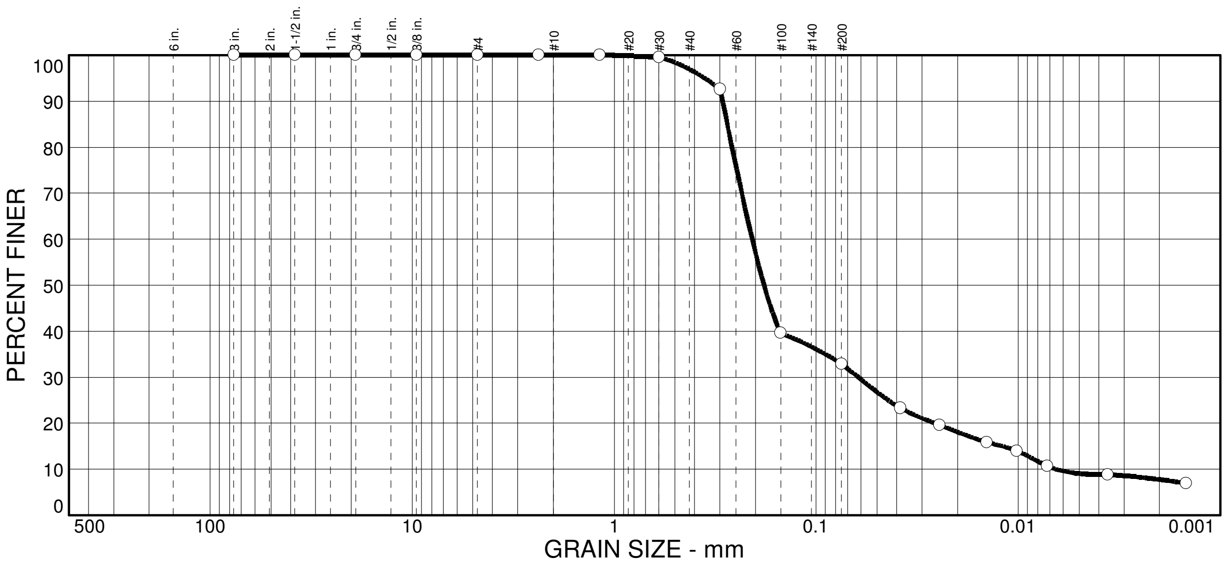
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2032
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195900 **Source of Sample:** **Date:** 10/21/13
Location: LS-D6A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	3.0	64.1	23.8	9.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.6		
#50	92.6		
#100	39.6		
#200	32.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.276 D_{60}= 0.208 D_{50}= 0.182
D_{30}= 0.0620 D_{15}= 0.0119 D_{10}= 0.0065
C_u= 32.08 C_c= 2.86

Classification

USCS= AASHTO=

Remarks

Figure

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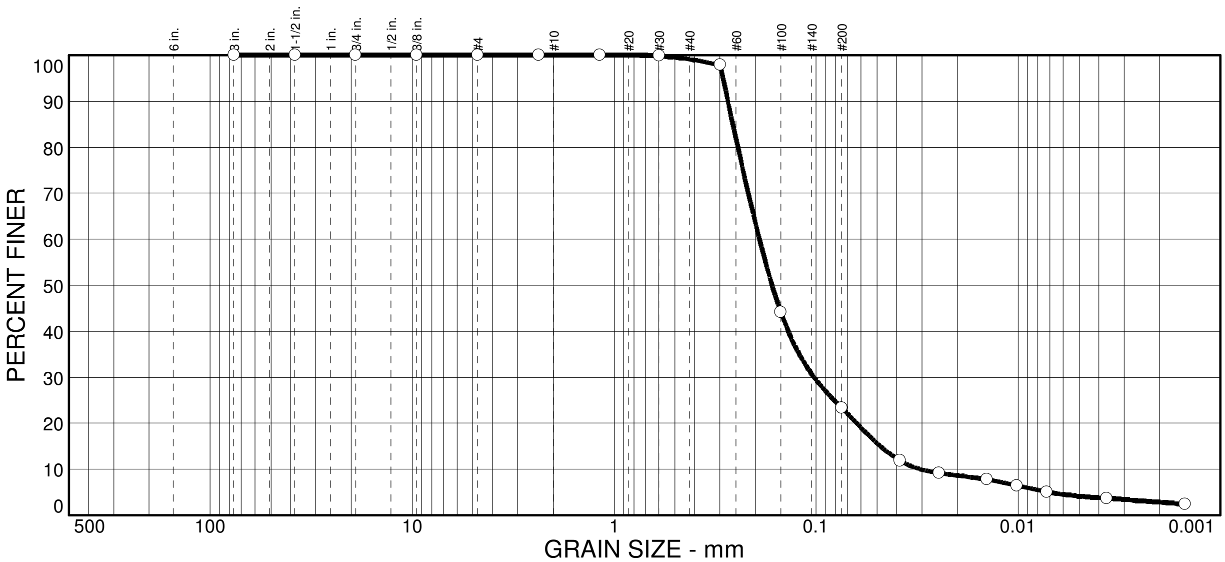
Report Number
13-301-2033

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2033
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195901 **Source of Sample:** **Date:** 10/21/13
Location: LS-D6B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.9	75.7	19.2	4.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.9		
#50	97.9		
#100	44.2		
#200	23.4		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.259 D_{60}= 0.191 D_{50}= 0.166
D_{30}= 0.103 D_{15}= 0.0482 D_{10}= 0.0304
C_u= 6.30 C_c= 1.81

Classification

USCS= AASHTO=

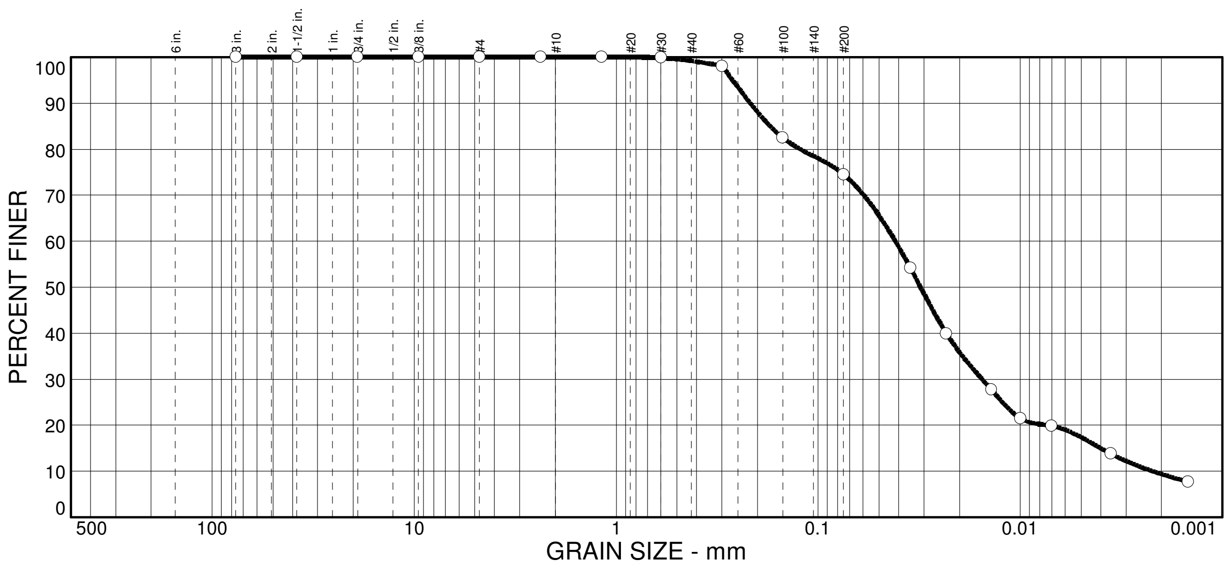
Remarks

Figure

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2034
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195902 **Source of Sample:** **Date:** 10/21/13
Location: LS-D6C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.8	24.7	57.1	17.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.9		
#50	98.1		
#100	82.5		
#200	74.5		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.173 D_{60}= 0.0416 D_{50}= 0.0312
D_{30}= 0.0155 D_{15}= 0.0040 D_{10}= 0.0022
C_u= 18.82 C_c= 2.60

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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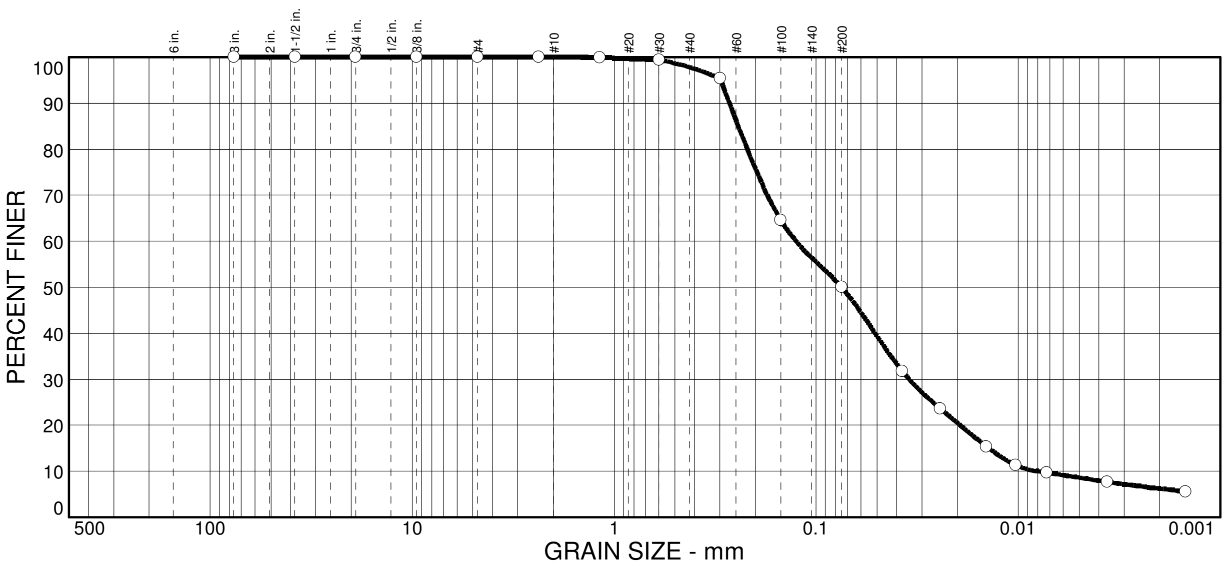
Report Number
13-301-2035

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2035
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195903 **Source of Sample:** **Date:** 10/21/13
Location: LS-D6D **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	2.1	47.9	41.4	8.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.9		
#30	99.4		
#50	95.4		
#100	64.6		
#200	50.0		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.243 D_{60}= 0.126 D_{50}= 0.0750
D_{30}= 0.0347 D_{15}= 0.0140 D_{10}= 0.0080
C_u= 15.74 C_c= 1.19

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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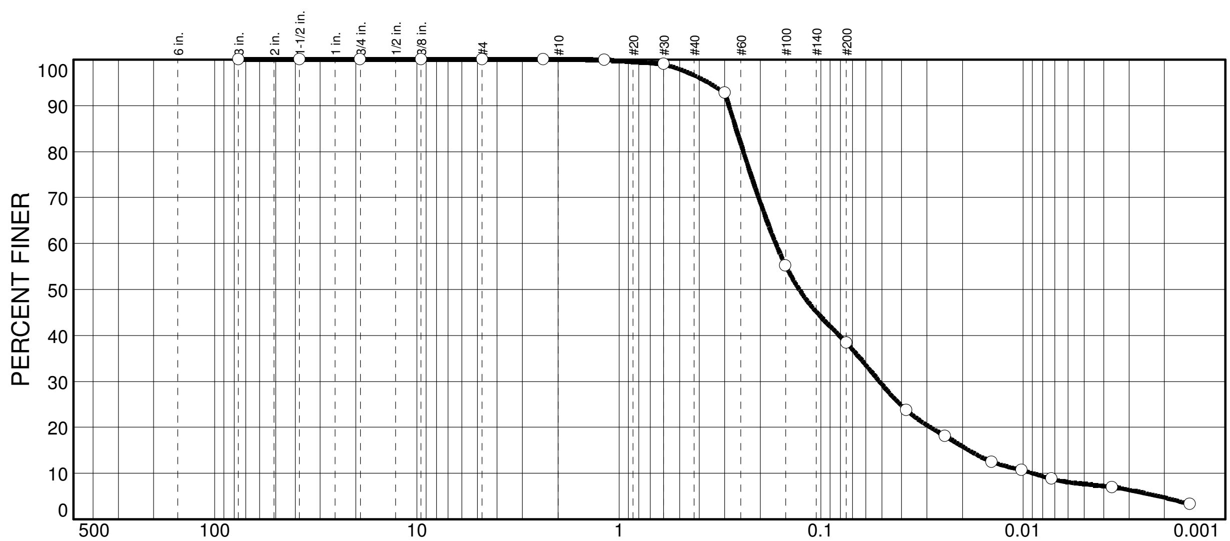
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2036
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195904 **Source of Sample:** **Date:** 10/21/13
Location: LS-D6E **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	3.4	58.2	30.7	7.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.9		
#30	99.0		
#50	92.8		
#100	55.2		
#200	38.4		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.264 D_{60}= 0.168 D_{50}= 0.129
D_{30}= 0.0516 D_{15}= 0.0186 D_{10}= 0.0090
C_u= 18.75 C_c= 1.77

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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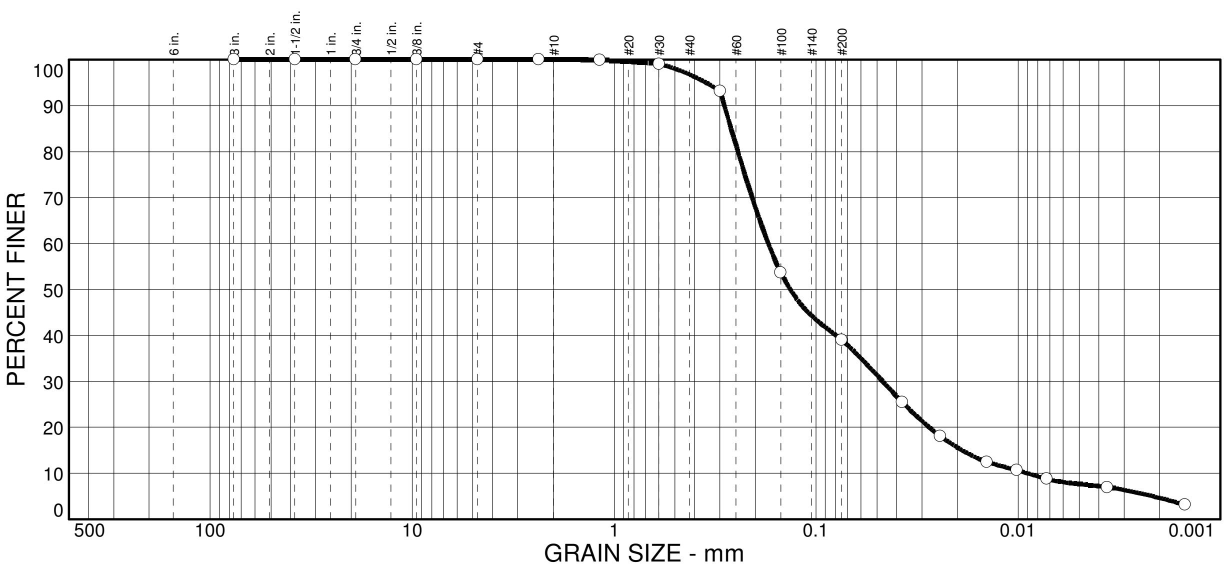
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2036
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195904 DUP **Source of Sample:** **Date:** 10/21/13
Location: LS-D6E DUP **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	3.2	57.8	31.3	7.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	99.9		
#30	99.1		
#50	93.2		
#100	53.7		
#200	39.0		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.264 D_{60}= 0.173 D_{50}= 0.135
D_{30}= 0.0469 D_{15}= 0.0190 D_{10}= 0.0090
C_u= 19.28 C_c= 1.42

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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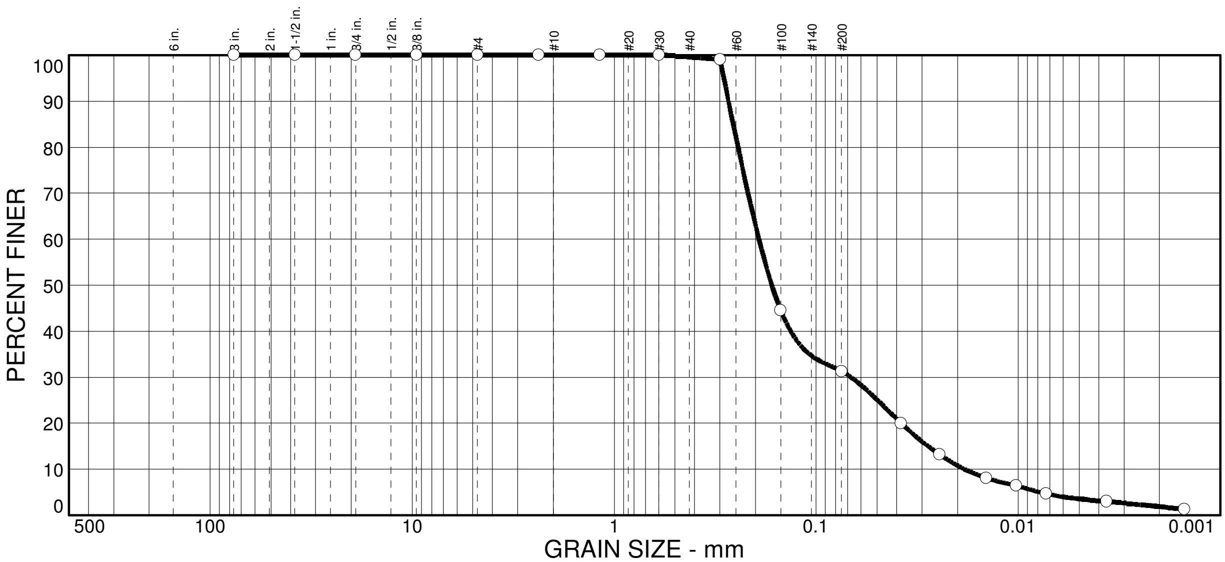
Report Number
13-301-2037

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2037
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195905 **Source of Sample:** **Date:** 10/16/13
Location: LS-D7A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.4	68.3	27.7	3.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.0		
#100	44.5		
#200	31.3		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.258 D_{60}= 0.192 D_{50}= 0.166
D_{30}= 0.0674 D_{15}= 0.0280 D_{10}= 0.0185
C_u= 10.43 C_c= 1.28

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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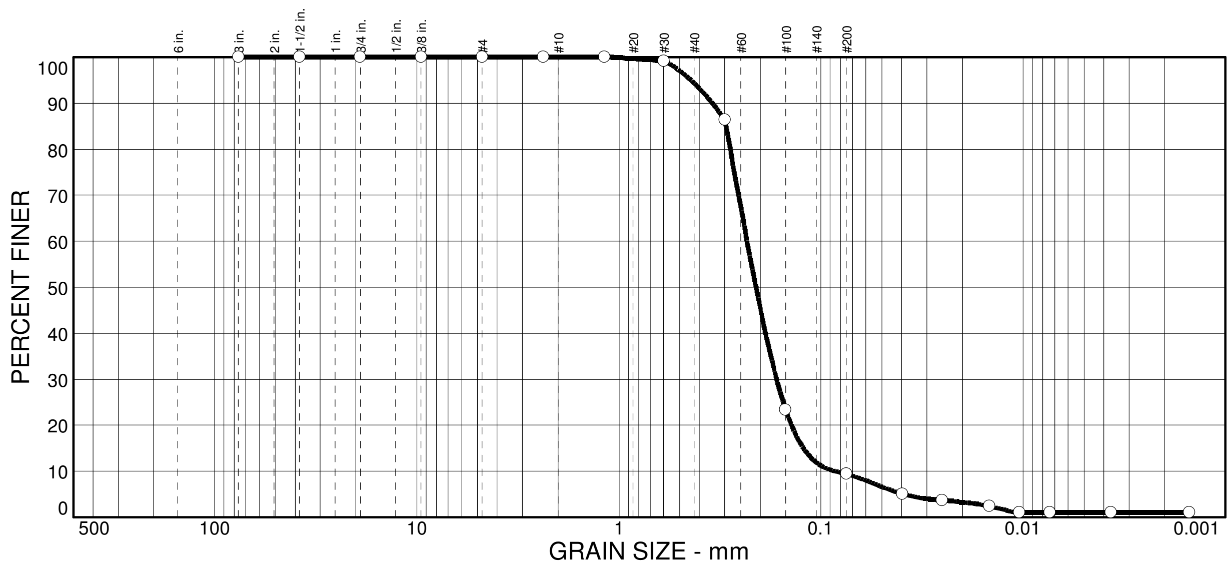
Report Number
13-301-2038

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2038
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195906 **Source of Sample:** **Date:** 10/16/13
Location: LS-D7B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	5.7	84.9	8.4	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.2		
#50	86.4		
#100	23.4		
#200	9.4		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.296 D_{60}= 0.233 D_{50}= 0.210
D_{30}= 0.166 D_{15}= 0.122 D_{10}= 0.0853
C_u= 2.73 C_c= 1.39

Classification

USCS= AASHTO=

Remarks

Figure

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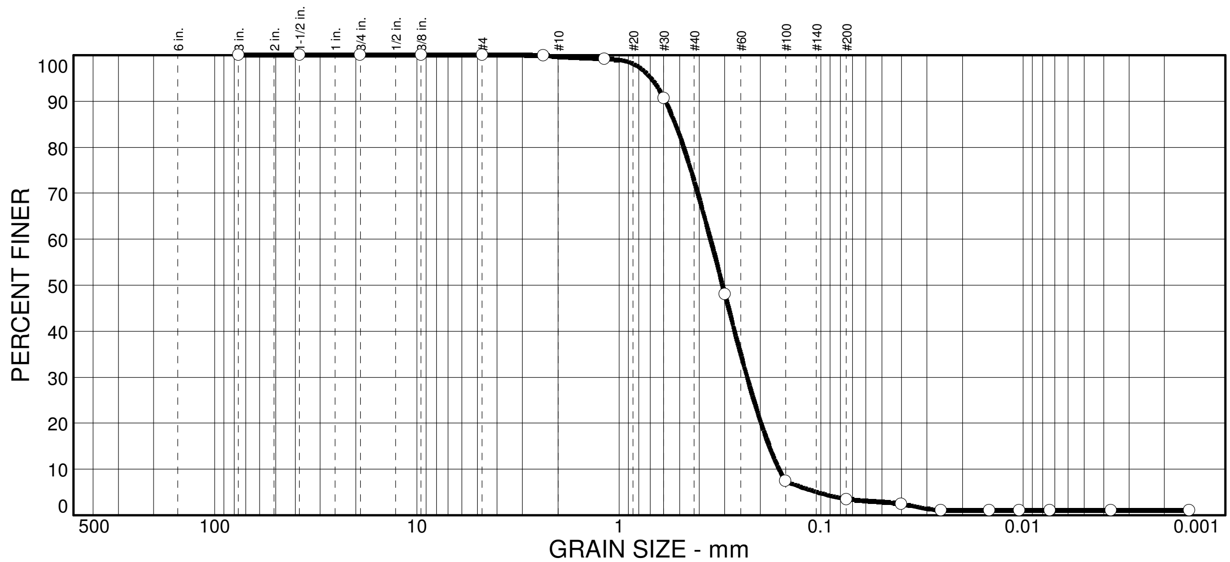
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2039

Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195907 **Source of Sample:** **Date:** 10/16/13

Location: LS-D7C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.3	27.0	69.2	2.5	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	99.9		
#16	99.2		
#30	90.7		
#50	48.1		
#100	7.4		
#200	3.5		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.526 D_{60}= 0.353 D_{50}= 0.308

D_{30}= 0.233 D_{15}= 0.181 D_{10}= 0.162

C_u= 2.19 C_c= 0.95

Classification

USCS= AASHTO=

Remarks

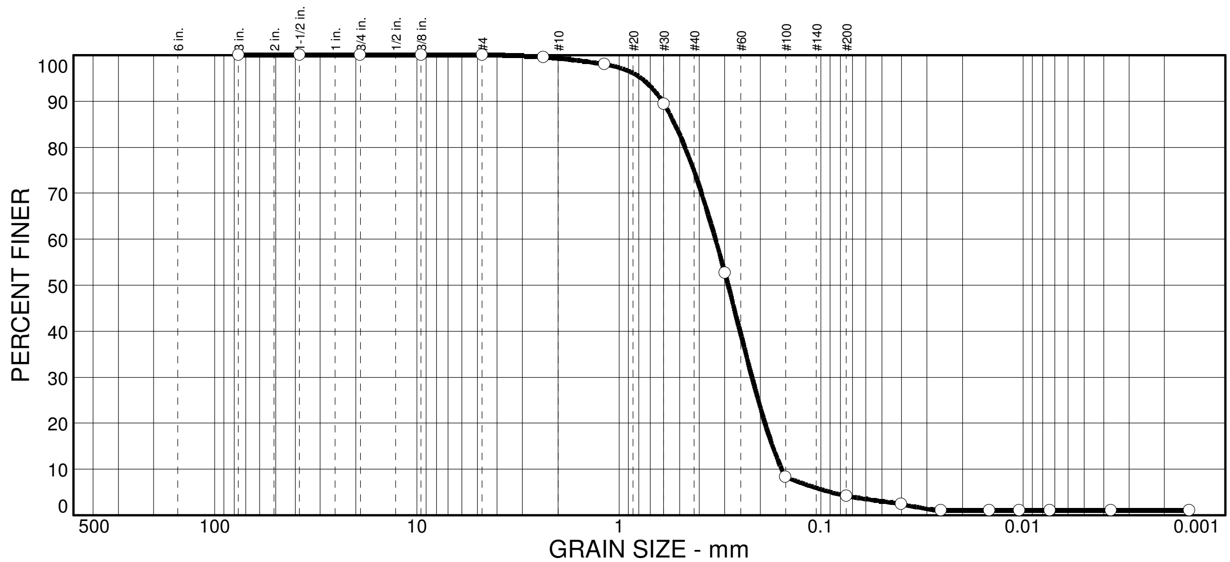
* (no specification provided)

Figure

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2040
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195908 **Source of Sample:** **Date:** 10/16/13
Location: LS-D7D **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.7	24.7	70.4	3.2	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	99.6		
#16	98.0		
#30	89.4		
#50	52.7		
#100	8.3		
#200	4.2		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.529 D_{60}= 0.333 D_{50}= 0.289
D_{30}= 0.220 D_{15}= 0.174 D_{10}= 0.157
C_u= 2.13 C_c= 0.93

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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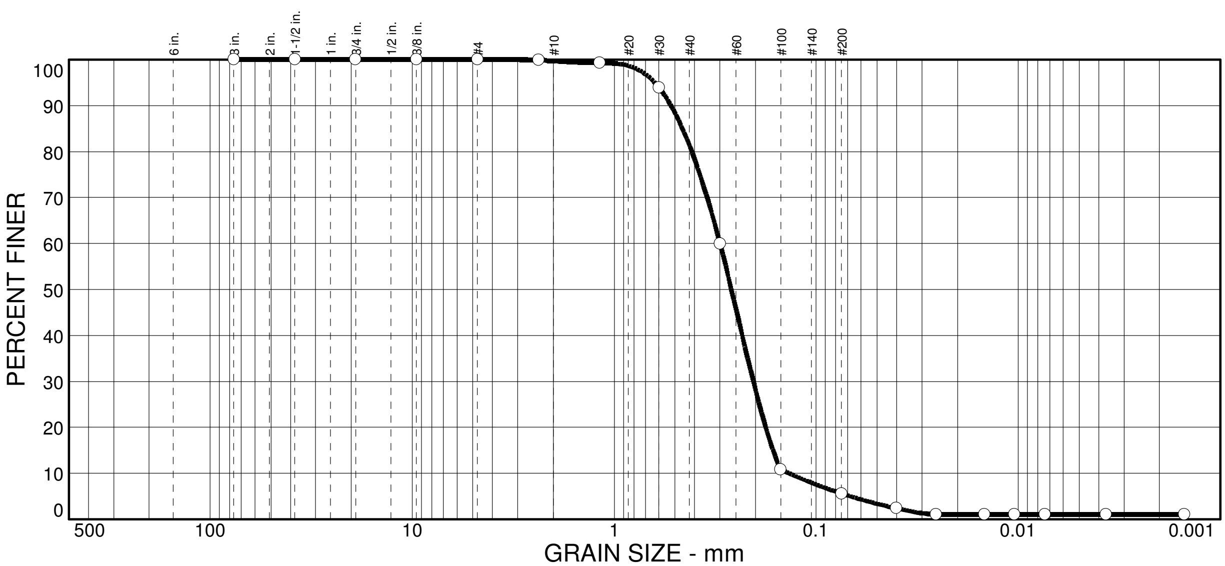
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2041
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195909 **Source of Sample:** **Date:** 10/16/13
Location: LS-D7E **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.3	18.4	75.7	4.6	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	99.9		
#16	99.3		
#30	93.9		
#50	60.0		
#100	10.8		
#200	5.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.460 D_{60}= 0.300 D_{50}= 0.264
D_{30}= 0.205 D_{15}= 0.164 D_{10}= 0.137
C_u= 2.20 C_c= 1.03

Classification

USCS= AASHTO=

Remarks

Figure

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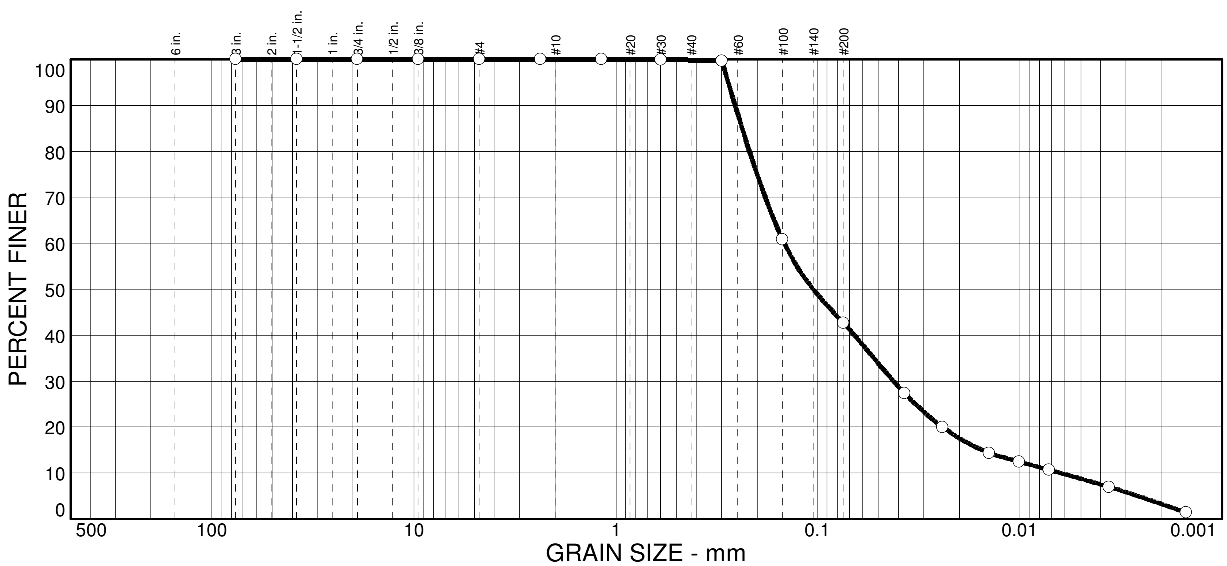
Report Number
13-301-2042

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2042
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195910 **Source of Sample:** **Date:** 10/16/13
Location: LS-D8A **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.2	57.1	33.9	8.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	99.9		
#50	99.7		
#100	60.8		
#200	42.7		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.238 D_{60}= 0.147 D_{50}= 0.106
D_{30}= 0.0423 D_{15}= 0.0154 D_{10}= 0.0063
C_u= 23.37 C_c= 1.94

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

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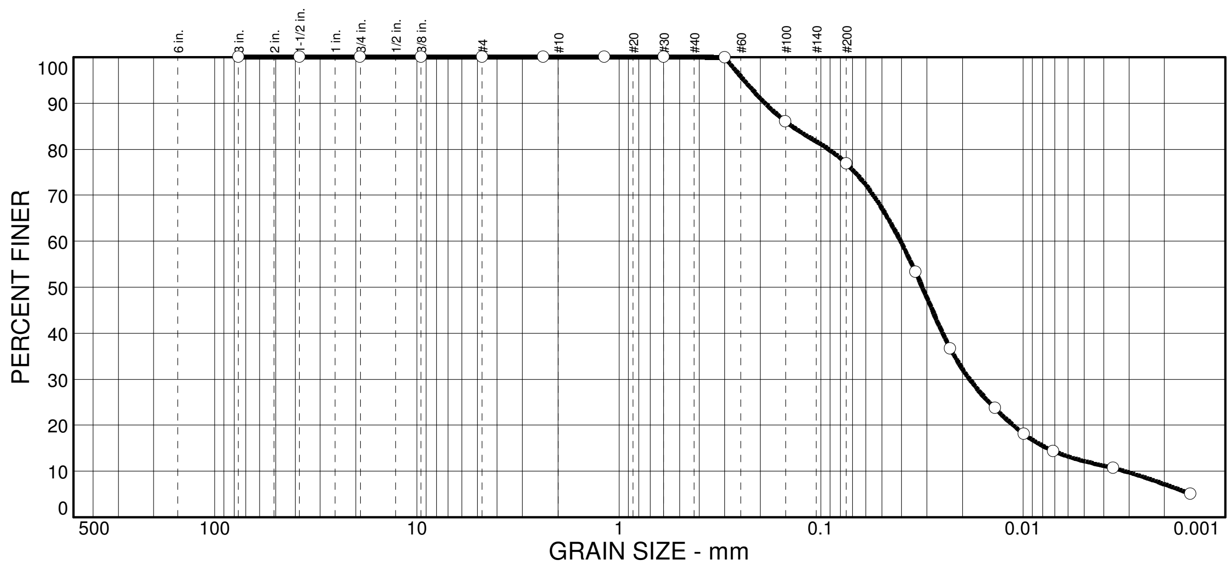
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2043
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195911 **Source of Sample:** **Date:** 10/16/13
Location: LS-D8B **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.0	23.1	64.7	12.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.9		
#100	86.0		
#200	76.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.140 D_{60}= 0.0405 D_{50}= 0.0316
D_{30}= 0.0185 D_{15}= 0.0076 D_{10}= 0.0031
C_u= 12.89 C_c= 2.69

Classification

USCS= AASHTO=

Remarks

Figure

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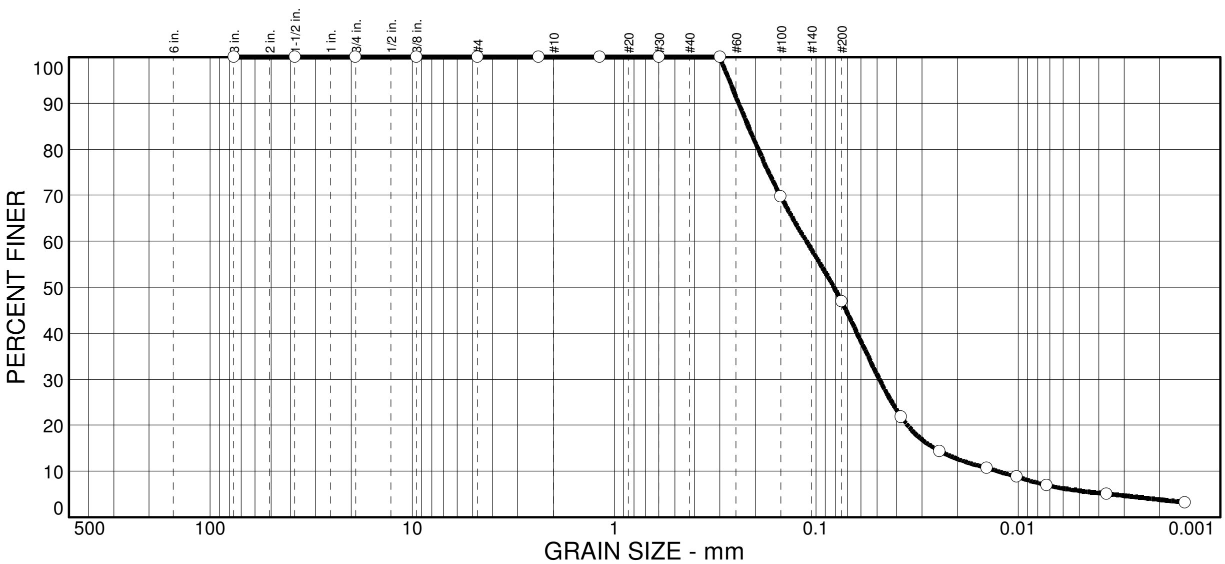
Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2044

Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195912 **Source of Sample:** **Date:** 10/16/13

Location: LS-D8C **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.0	53.1	41.1	5.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	100.0		
#100	69.7		
#200	46.9		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.217 D_{60}= 0.112 D_{50}= 0.0819

D_{30}= 0.0487 D_{15}= 0.0260 D_{10}= 0.0126

C_u= 8.86 C_c= 1.68

Classification

USCS= AASHTO=

Remarks

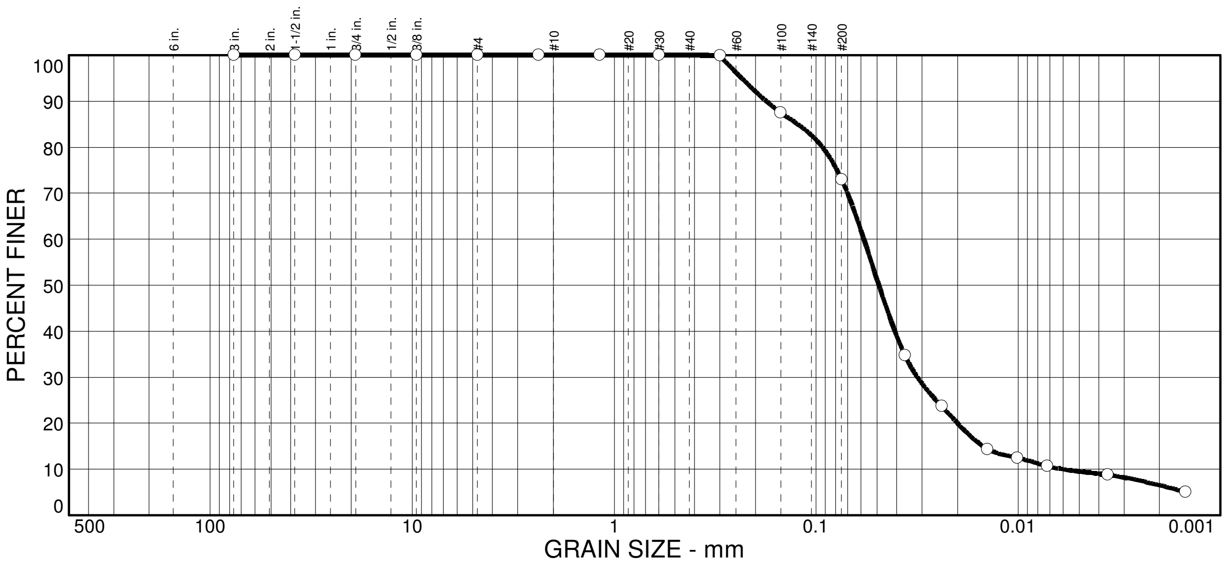
* (no specification provided)

Figure

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2045
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195913 **Source of Sample:** **Date:** 10/16/13
Location: LS-D8D **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.0	27.0	63.5	9.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.9		
#100	87.5		
#200	73.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.124 D_{60}= 0.0582 D_{50}= 0.0491
D_{30}= 0.0316 D_{15}= 0.0150 D_{10}= 0.0060
C_u= 9.71 C_c= 2.87

Classification

USCS= AASHTO=

Remarks

Figure

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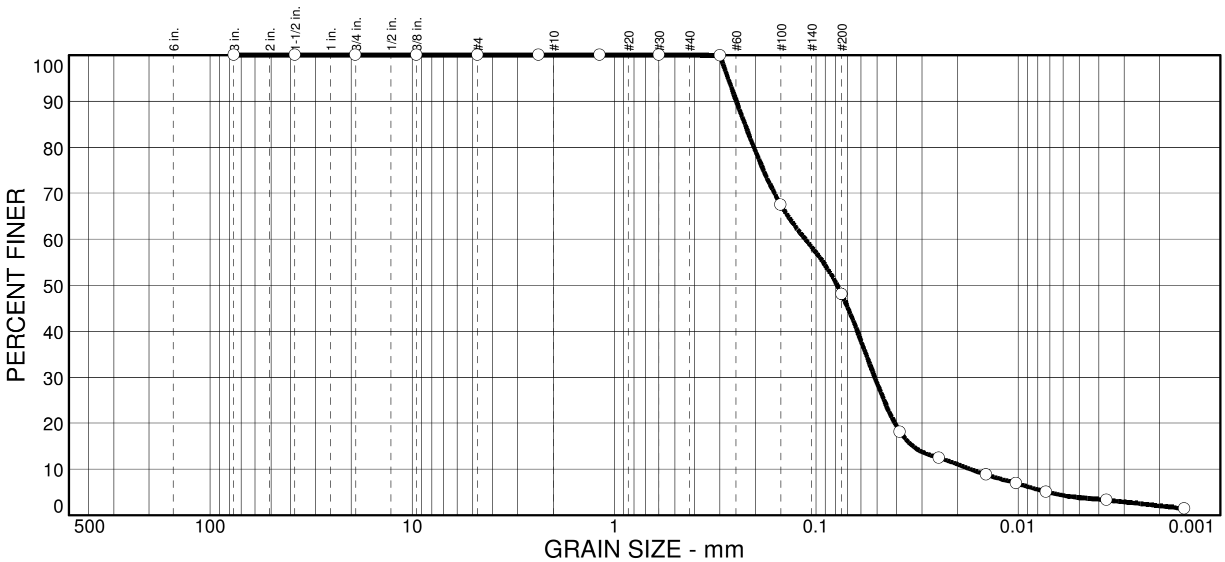
Report Number
13-301-2046

Particle Size Distribution Report

Project: LITTLE SIOUX SWH SEDIMENT **Report No.:** 13-301-2046
Client: US ARMY CORPS OF ENGINEERS

Sample No: 2195914 **Source of Sample:** **Date:** 10/16/13
Location: LS-D8E **Elev./Depth:**



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.0	51.9	44.2	3.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0		
#4	100.0		
#8	100.0		
#16	100.0		
#30	100.0		
#50	99.9		
#100	67.5		
#200	48.1		

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.226 D_{60}= 0.113 D_{50}= 0.0789
D_{30}= 0.0514 D_{15}= 0.0333 D_{10}= 0.0173
C_u= 6.58 C_c= 1.35

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Figure

Attachment 3

Laboratory Analytical Results

Station	Date	Time	Depth	SampleSource	Analyte	Result	Units	Method	DF	MDL	MRL	AnalysisDate	LabNumber
LS-D1A	10/21/2013	14:30	0-2	Composite	Nitrate/Nitrite Nitrogen	1.1	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-01
LS-D1A	10/21/2013	14:30	0-2	Composite	Percent Solids	92.87	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-01
LS-D1A	10/21/2013	14:30	0-2	Composite	Phosphorus (Total)	380.1	mg/kg dry	EPA 6010B	51.65	0.9	5.6	23-Oct-13	1300897-01
LS-D1A	10/21/2013	14:30	0-2	Composite	Total Kjeldahl Nitrogen	205	mg/kg dry	PAI-DK 01	5	1.5	26.9	24-Oct-13	1300897-01
LS-D1B	10/21/2013	14:30	2-4	Composite	Nitrate/Nitrite Nitrogen	1.2	mg/kg dry	EPA 353.2	5	0.04	1	28-Oct-13	1300897-02
LS-D1B	10/21/2013	14:30	2-4	Composite	Percent Solids	95.68	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-02
LS-D1B	10/21/2013	14:30	2-4	Composite	Phosphorus (Total)	294.6	mg/kg dry	EPA 6010B	46.73	0.8	4.9	23-Oct-13	1300897-02
LS-D1B	10/21/2013	14:30	2-4	Composite	Total Kjeldahl Nitrogen	81	mg/kg dry	PAI-DK 01	5	1.4	26.1	24-Oct-13	1300897-02
LS-D1C	10/21/2013	14:30	4-6	Composite	Nitrate/Nitrite Nitrogen	1.3	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-03
LS-D1C	10/21/2013	14:30	4-6	Composite	Percent Solids	82.16	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-03
LS-D1C	10/21/2013	14:30	4-6	Composite	Phosphorus (Total)	369.8	mg/kg dry	EPA 6010B	47.26	1	5.8	23-Oct-13	1300897-03
LS-D1C	10/21/2013	14:30	4-6	Composite	Total Kjeldahl Nitrogen	159	mg/kg dry	PAI-DK 01	5	1.7	30.4	24-Oct-13	1300897-03
LS-D1D	10/21/2013	14:30	6-8	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.3	28-Oct-13	1300897-04
LS-D1D	10/21/2013	14:30	6-8	Composite	Percent Solids	75.61	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-04
LS-D1D	10/21/2013	14:30	6-8	Composite	Phosphorus (Total)	470.7	mg/kg dry	EPA 6010B	49.53	1.1	6.6	24-Oct-13	1300897-04
LS-D1D	10/21/2013	14:30	6-8	Composite	Total Kjeldahl Nitrogen	398	mg/kg dry	PAI-DK 01	5	1.8	33.1	24-Oct-13	1300897-04
LS-D1E	10/21/2013	14:30	8-10	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.3	28-Oct-13	1300897-05
LS-D1E	10/21/2013	14:30	8-10	Composite	Percent Solids	75.65	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-05
LS-D1E	10/21/2013	14:30	8-10	Composite	Phosphorus (Total)	435.4	mg/kg dry	EPA 6010B	44.19	1	5.8	24-Oct-13	1300897-05
LS-D1E	10/21/2013	14:30	8-10	Composite	Total Kjeldahl Nitrogen	223	mg/kg dry	PAI-DK 01	5	1.8	33	24-Oct-13	1300897-05
LS-D2A	10/21/2013	13:10	0-2	Composite	Nitrate/Nitrite Nitrogen	2.3	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-06
LS-D2A	10/21/2013	13:10	0-2	Composite	Percent Solids	82.75	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-06
LS-D2A	10/21/2013	13:10	0-2	Composite	Phosphorus (Total)	575.8	mg/kg dry	EPA 6010B	47.73	1	5.8	24-Oct-13	1300897-06
LS-D2A	10/21/2013	13:10	0-2	Composite	Total Kjeldahl Nitrogen	1070	mg/kg dry	PAI-DK 01	5	1.6	30.2	24-Oct-13	1300897-06
LS-D2B	10/21/2013	13:10	2-4	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-07
LS-D2B	10/21/2013	13:10	2-4	Composite	Percent Solids	83.08	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-07
LS-D2B	10/21/2013	13:10	2-4	Composite	Phosphorus (Total)	466.6	mg/kg dry	EPA 6010B	47.66	1	5.7	24-Oct-13	1300897-07
LS-D2B	10/21/2013	13:10	2-4	Composite	Total Kjeldahl Nitrogen	235	mg/kg dry	PAI-DK 01	5	1.6	30.1	24-Oct-13	1300897-07
LS-D2C	10/21/2013	13:10	4-6	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.4	28-Oct-13	1300897-08
LS-D2C	10/21/2013	13:10	4-6	Composite	Percent Solids	73.95	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-08
LS-D2C	10/21/2013	13:10	4-6	Composite	Phosphorus (Total)	499.6	mg/kg dry	EPA 6010B	47.73	1.1	6.5	24-Oct-13	1300897-08
LS-D2C	10/21/2013	13:10	4-6	Composite	Total Kjeldahl Nitrogen	349	mg/kg dry	PAI-DK 01	5	1.8	33.8	24-Oct-13	1300897-08
LS-D2D	10/21/2013	13:10	6-8	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.4	28-Oct-13	1300897-09
LS-D2D	10/21/2013	13:10	6-8	Composite	Percent Solids	73.76	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-09
LS-D2D	10/21/2013	13:10	6-8	Composite	Phosphorus (Total)	418.4	mg/kg dry	EPA 6010B	45.02	1	6.1	24-Oct-13	1300897-09
LS-D2D	10/21/2013	13:10	6-8	Composite	Total Kjeldahl Nitrogen	136	mg/kg dry	PAI-DK 01	5	1.9	33.9	24-Oct-13	1300897-09
LS-D3A	10/21/2013	12:30	0-2	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-10
LS-D3A	10/21/2013	12:30	0-2	Composite	Percent Solids	87.57	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-10
LS-D3A	10/21/2013	12:30	0-2	Composite	Phosphorus (Total)	577.8	mg/kg dry	EPA 6010B	50.45	1	5.8	24-Oct-13	1300897-10
LS-D3A	10/21/2013	12:30	0-2	Composite	Total Kjeldahl Nitrogen	613	mg/kg dry	PAI-DK 01	5	1.6	28.5	24-Oct-13	1300897-10
LS-D3B	10/21/2013	12:30	2-4	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1	28-Oct-13	1300897-11
LS-D3B	10/21/2013	12:30	2-4	Composite	Percent Solids	95.92	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-11
LS-D3B	10/21/2013	12:30	2-4	Composite	Phosphorus (Total)	380.5	mg/kg dry	EPA 6010B	48.88	0.9	5.1	24-Oct-13	1300897-11
LS-D3B	10/21/2013	12:30	2-4	Composite	Total Kjeldahl Nitrogen	195	mg/kg dry	PAI-DK 01	5	1.4	26.1	24-Oct-13	1300897-11
LS-D3C	10/21/2013	12:30	4-6	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1	28-Oct-13	1300897-12
LS-D3C	10/21/2013	12:30	4-6	Composite	Percent Solids	97.73	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-12

Station	Date	Time	Depth	SampleSource	Analyte	Result	Units	Method	DF	MDL	MRL	AnalysisDate	LabNumber
LS-D3C	10/21/2013	12:30	4-6	Composite	Phosphorus (Total)	343.4	mg/kg dry	EPA 6010B	49.38	0.9	5.1	24-Oct-13	1300897-12
LS-D3C	10/21/2013	12:30	4-6	Composite	Total Kjeldahl Nitrogen	67.6	mg/kg dry	PAI-DK 01	5	1.4	25.6	24-Oct-13	1300897-12
LS-D3D	10/21/2013	12:30	6-8	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1	28-Oct-13	1300897-13
LS-D3D	10/21/2013	12:30	6-8	Composite	Percent Solids	97.14	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-13
LS-D3D	10/21/2013	12:30	6-8	Composite	Phosphorus (Total)	332.4	mg/kg dry	EPA 6010B	51.95	0.9	5.3	24-Oct-13	1300897-13
LS-D3D	10/21/2013	12:30	6-8	Composite	Total Kjeldahl Nitrogen	74	mg/kg dry	PAI-DK 01	5	1.4	25.7	24-Oct-13	1300897-13
LS-D3E	10/21/2013	12:30	8-10	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-14
LS-D3E	10/21/2013	12:30	8-10	Composite	Percent Solids	90.59	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-14
LS-D3E	10/21/2013	12:30	8-10	Composite	Phosphorus (Total)	387.9	mg/kg dry	EPA 6010B	48.78	0.9	5.4	24-Oct-13	1300897-14
LS-D3E	10/21/2013	12:30	8-10	Composite	Total Kjeldahl Nitrogen	120	mg/kg dry	PAI-DK 01	5	1.5	27.6	24-Oct-13	1300897-14
LS-D4A	10/21/2013	11:50	0-2	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-15
LS-D4A	10/21/2013	11:50	0-2	Composite	Percent Solids	90.87	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-15
LS-D4A	10/21/2013	11:50	0-2	Composite	Phosphorus (Total)	518.8	mg/kg dry	EPA 6010B	52.55	1	5.8	24-Oct-13	1300897-15
LS-D4A	10/21/2013	11:50	0-2	Composite	Total Kjeldahl Nitrogen	681	mg/kg dry	PAI-DK 01	5	1.5	27.5	24-Oct-13	1300897-15
LS-D4B	10/21/2013	11:50	2-4	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1	28-Oct-13	1300897-16
LS-D4B	10/21/2013	11:50	2-4	Composite	Percent Solids	97.33	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-16
LS-D4B	10/21/2013	11:50	2-4	Composite	Phosphorus (Total)	356	mg/kg dry	EPA 6010B	50.45	0.9	5.2	24-Oct-13	1300897-16
LS-D4B	10/21/2013	11:50	2-4	Composite	Total Kjeldahl Nitrogen	110	mg/kg dry	PAI-DK 01	5	1.4	25.7	25-Oct-13	1300897-16
LS-D4C	10/21/2013	11:50	4-6	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1	28-Oct-13	1300897-17
LS-D4C	10/21/2013	11:50	4-6	Composite	Percent Solids	97.11	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-17
LS-D4C	10/21/2013	11:50	4-6	Composite	Phosphorus (Total)	331.1	mg/kg dry	EPA 6010B	46.58	0.8	4.8	24-Oct-13	1300897-17
LS-D4C	10/21/2013	11:50	4-6	Composite	Total Kjeldahl Nitrogen	52.3	mg/kg dry	PAI-DK 01	5	1.4	25.7	25-Oct-13	1300897-17
LS-D4D	10/21/2013	11:50	6-8	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-18
LS-D4D	10/21/2013	11:50	6-8	Composite	Percent Solids	89.97	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-18
LS-D4D	10/21/2013	11:50	6-8	Composite	Phosphorus (Total)	321.7	mg/kg dry	EPA 6010B	44.56	0.8	5	24-Oct-13	1300897-18
LS-D4D	10/21/2013	11:50	6-8	Composite	Total Kjeldahl Nitrogen	64.4	mg/kg dry	PAI-DK 01	5	1.5	27.8	25-Oct-13	1300897-18
LS-D4E	10/21/2013	11:50	8-10	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.3	28-Oct-13	1300897-19
LS-D4E	10/21/2013	11:50	8-10	Composite	Percent Solids	76.09	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-19
LS-D4E	10/21/2013	11:50	8-10	Composite	Phosphorus (Total)	317.6	mg/kg dry	EPA 6010B	47.87	1.1	6.3	24-Oct-13	1300897-19
LS-D4E	10/21/2013	11:50	8-10	Composite	Total Kjeldahl Nitrogen	76.5	mg/kg dry	PAI-DK 01	5	1.8	32.9	25-Oct-13	1300897-19
LS-D5A	10/21/2013	10:20	0-2	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-20
LS-D5A	10/21/2013	10:20	0-2	Composite	Percent Solids	83.04	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-20
LS-D5A	10/21/2013	10:20	0-2	Composite	Phosphorus (Total)	449	mg/kg dry	EPA 6010B	47.64	1	5.7	24-Oct-13	1300897-20
LS-D5A	10/21/2013	10:20	0-2	Composite	Total Kjeldahl Nitrogen	181	mg/kg dry	PAI-DK 01	5	1.6	30.1	25-Oct-13	1300897-20
LS-D5B	10/21/2013	10:20	2-4	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-21
LS-D5B	10/21/2013	10:20	2-4	Composite	Percent Solids	80.21	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-21
LS-D5B	10/21/2013	10:20	2-4	Composite	Phosphorus (Total)	294	mg/kg dry	EPA 6010B	49.95	1.1	6.2	24-Oct-13	1300897-21
LS-D5B	10/21/2013	10:20	2-4	Composite	Total Kjeldahl Nitrogen	73.3	mg/kg dry	PAI-DK 01	5	1.7	31.2	25-Oct-13	1300897-21
LS-D5C	10/21/2013	10:20	4-6	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.3	28-Oct-13	1300897-22
LS-D5C	10/21/2013	10:20	4-6	Composite	Percent Solids	78.7	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-22
LS-D5C	10/21/2013	10:20	4-6	Composite	Phosphorus (Total)	374.1	mg/kg dry	EPA 6010B	45.81	1	5.8	24-Oct-13	1300897-22
LS-D5C	10/21/2013	10:20	4-6	Composite	Total Kjeldahl Nitrogen	121	mg/kg dry	PAI-DK 01	5	1.7	31.8	25-Oct-13	1300897-22
LS-D6A	10/21/2013	9:30	0-2	Composite	Nitrate/Nitrite Nitrogen	1.5	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-23
LS-D6A	10/21/2013	9:30	0-2	Composite	Percent Solids	91.05	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-23
LS-D6A	10/21/2013	9:30	0-2	Composite	Phosphorus (Total)	481.4	mg/kg dry	EPA 6010B	50.28	0.9	5.5	24-Oct-13	1300897-23

Station	Date	Time	Depth	SampleSource	Analyte	Result	Units	Method	DF	MDL	MRL	AnalysisDate	LabNumber
LS-D6A	10/21/2013	9:30	0-2	Composite	Total Kjeldahl Nitrogen	563	mg/kg dry	PAI-DK 01	5	1.5	27.5	25-Oct-13	1300897-23
LS-D6B	10/21/2013	9:30	2-4	Composite	Nitrate/Nitrite Nitrogen	1.4	mg/kg dry	EPA 353.2	5	0.04	1.3	28-Oct-13	1300897-24
LS-D6B	10/21/2013	9:30	2-4	Composite	Percent Solids	79.44	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-24
LS-D6B	10/21/2013	9:30	2-4	Composite	Phosphorus (Total)	409.4	mg/kg dry	EPA 6010B	51.65	1.1	6.5	24-Oct-13	1300897-24
LS-D6B	10/21/2013	9:30	2-4	Composite	Total Kjeldahl Nitrogen	290	mg/kg dry	PAI-DK 01	5	1.7	31.5	25-Oct-13	1300897-24
LS-D6C	10/21/2013	9:30	4-6	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.4	28-Oct-13	1300897-25
LS-D6C	10/21/2013	9:30	4-6	Composite	Percent Solids	72.7	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-25
LS-D6C	10/21/2013	9:30	4-6	Composite	Phosphorus (Total)	624	mg/kg dry	EPA 6010B	49.29	1.2	6.8	24-Oct-13	1300897-25
LS-D6C	10/21/2013	9:30	4-6	Composite	Total Kjeldahl Nitrogen	769	mg/kg dry	PAI-DK 01	5	1.9	34.4	25-Oct-13	1300897-25
LS-D6D	10/21/2013	9:30	6-8	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.4	28-Oct-13	1300897-26
LS-D6D	10/21/2013	9:30	6-8	Composite	Percent Solids	72.54	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-26
LS-D6D	10/21/2013	9:30	6-8	Composite	Phosphorus (Total)	583.7	mg/kg dry	EPA 6010B	51.12	1.2	7	24-Oct-13	1300897-26
LS-D6D	10/21/2013	9:30	6-8	Composite	Total Kjeldahl Nitrogen	652	mg/kg dry	PAI-DK 01	5	1.9	34.5	25-Oct-13	1300897-26
LS-D6E	10/21/2013	9:30	8-10	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.3	28-Oct-13	1300897-27
LS-D6E	10/21/2013	9:30	8-10	Composite	Percent Solids	76.55	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-27
LS-D6E	10/21/2013	9:30	8-10	Composite	Phosphorus (Total)	515.9	mg/kg dry	EPA 6010B	51.41	1.1	6.7	24-Oct-13	1300897-27
LS-D6E	10/21/2013	9:30	8-10	Composite	Total Kjeldahl Nitrogen	387	mg/kg dry	PAI-DK 01	5	1.8	32.7	25-Oct-13	1300897-27
LS-D7A	10/16/2013	15:00	0-2	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-28
LS-D7A	10/16/2013	15:00	0-2	Composite	Percent Solids	86.09	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-28
LS-D7A	10/16/2013	15:00	0-2	Composite	Phosphorus (Total)	460.7	mg/kg dry	EPA 6010B	50.15	1	5.8	24-Oct-13	1300897-28
LS-D7A	10/16/2013	15:00	0-2	Composite	Total Kjeldahl Nitrogen	143	mg/kg dry	PAI-DK 01	5	1.6	29	25-Oct-13	1300897-28
LS-D7B	10/16/2013	15:00	2-4	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-29
LS-D7B	10/16/2013	15:00	2-4	Composite	Percent Solids	95.11	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-29
LS-D7B	10/16/2013	15:00	2-4	Composite	Phosphorus (Total)	351.4	mg/kg dry	EPA 6010B	50.25	0.9	5.3	24-Oct-13	1300897-29
LS-D7B	10/16/2013	15:00	2-4	Composite	Total Kjeldahl Nitrogen	81.6	mg/kg dry	PAI-DK 01	5	1.4	26.3	25-Oct-13	1300897-29
LS-D7C	10/16/2013	15:00	4-6	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1	28-Oct-13	1300897-30
LS-D7C	10/16/2013	15:00	4-6	Composite	Percent Solids	96.33	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-30
LS-D7C	10/16/2013	15:00	4-6	Composite	Phosphorus (Total)	275.8	mg/kg dry	EPA 6010B	48.43	0.9	5	24-Oct-13	1300897-30
LS-D7C	10/16/2013	15:00	4-6	Composite	Total Kjeldahl Nitrogen	76.1	mg/kg dry	PAI-DK 01	5	1.4	26	25-Oct-13	1300897-30
LS-D7D	10/16/2013	15:00	6-8	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-31
LS-D7D	10/16/2013	15:00	6-8	Composite	Percent Solids	88.56	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-31
LS-D7D	10/16/2013	15:00	6-8	Composite	Phosphorus (Total)	271.2	mg/kg dry	EPA 6010B	46.13	0.9	5.2	24-Oct-13	1300897-31
LS-D7D	10/16/2013	15:00	6-8	Composite	Total Kjeldahl Nitrogen	65.6	mg/kg dry	PAI-DK 01	5	1.5	28.2	25-Oct-13	1300897-31
LS-D7E	10/16/2013	15:00	8-10	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.3	28-Oct-13	1300897-32
LS-D7E	10/16/2013	15:00	8-10	Composite	Percent Solids	79.98	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-32
LS-D7E	10/16/2013	15:00	8-10	Composite	Phosphorus (Total)	331.7	mg/kg dry	EPA 6010B	49.29	1	6.2	24-Oct-13	1300897-32
LS-D7E	10/16/2013	15:00	8-10	Composite	Total Kjeldahl Nitrogen	65.1	mg/kg dry	PAI-DK 01	5	1.7	31.3	25-Oct-13	1300897-32
LS-D8A	10/16/2013	13:00	0-2	Composite	Nitrate/Nitrite Nitrogen	2.6	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-33
LS-D8A	10/16/2013	13:00	0-2	Composite	Percent Solids	85.19	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-33
LS-D8A	10/16/2013	13:00	0-2	Composite	Phosphorus (Total)	552.3	mg/kg dry	EPA 6010B	47.53	0.9	5.6	24-Oct-13	1300897-33
LS-D8A	10/16/2013	13:00	0-2	Composite	Total Kjeldahl Nitrogen	585	mg/kg dry	PAI-DK 01	5	1.6	29.3	25-Oct-13	1300897-33
LS-D8B	10/16/2013	13:00	2-4	Composite	Nitrate/Nitrite Nitrogen	2.4	mg/kg dry	EPA 353.2	5	0.04	1.2	28-Oct-13	1300897-34
LS-D8B	10/16/2013	13:00	2-4	Composite	Percent Solids	82.82	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-34
LS-D8B	10/16/2013	13:00	2-4	Composite	Phosphorus (Total)	575.1	mg/kg dry	EPA 6010B	48.92	1	5.9	24-Oct-13	1300897-34
LS-D8B	10/16/2013	13:00	2-4	Composite	Total Kjeldahl Nitrogen	499	mg/kg dry	PAI-DK 01	5	1.6	30.2	25-Oct-13	1300897-34
LS-D8C	10/16/2013	13:00	4-6	Composite	Nitrate/Nitrite Nitrogen	<0.04	mg/kg dry	EPA 353.2	5	0.04	1.1	28-Oct-13	1300897-35

Station	Date	Time	Depth	SampleSource	Analyte	Result	Units	Method	DF	MDL	MRL	AnalysisDate	LabNumber
LS-D8C	10/16/2013	13:00	4-6	Composite	Percent Solids	89.18	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-35
LS-D8C	10/16/2013	13:00	4-6	Composite	Phosphorus (Total)	502.9	mg/kg dry	EPA 6010B	48.8	0.9	5.5	24-Oct-13	1300897-35
LS-D8C	10/16/2013	13:00	4-6	Composite	Total Kjeldahl Nitrogen	261	mg/kg dry	PAI-DK 01	5	1.5	28	25-Oct-13	1300897-35
LS-D8D	10/16/2013	13:00	6-8	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.3	28-Oct-13	1300897-36
LS-D8D	10/16/2013	13:00	6-8	Composite	Percent Solids	77.76	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-36
LS-D8D	10/16/2013	13:00	6-8	Composite	Phosphorus (Total)	574.6	mg/kg dry	EPA 6010B	46.02	1	5.9	24-Oct-13	1300897-36
LS-D8D	10/16/2013	13:00	6-8	Composite	Total Kjeldahl Nitrogen	440	mg/kg dry	PAI-DK 01	5	1.8	32.2	25-Oct-13	1300897-36
LS-D8E	10/16/2013	13:00	8-10	Composite	Nitrate/Nitrite Nitrogen	<0.05	mg/kg dry	EPA 353.2	5	0.05	1.3	28-Oct-13	1300897-37
LS-D8E	10/16/2013	13:00	8-10	Composite	Percent Solids	76.27	%	SM 2540 G	1	0.01	0.01	25-Oct-13	1300897-37
LS-D8E	10/16/2013	13:00	8-10	Composite	Phosphorus (Total)	501.1	mg/kg dry	EPA 6010B	47.82	1.1	6.3	24-Oct-13	1300897-37
LS-D8E	10/16/2013	13:00	8-10	Composite	Total Kjeldahl Nitrogen	288	mg/kg dry	PAI-DK 01	5	1.8	32.8	25-Oct-13	1300897-37

Attachment 4

Phosphorus in Iowa Soils

PHOSPHORUS IN IOWA SOILS

T. E. Fenton
Agronomy Department
Iowa State University
December 3, 1999
tefenton@iastate.edu

Introduction

Phosphorus is a key element in all living things. It is also a major fertilizer element and a major component of manure. Excess phosphorus in bodies of water causes growth of algae and other aquatic plants and thus is of environmental concern. Phosphorus is also a dynamic element in soil genesis. The amount, distribution, and chemical composition of phosphorus in soils are closely related to the classic factors of soil formation-climate, organisms, parent material, topography, and time. Also, in the past 150 years in Iowa, human influence on soils and landscapes is an additional variable that contributes to changes in soil profile characteristics and properties. These changes include but are not limited to the properties associated with accelerated erosion and related deposition, fertilization, cultivation and resulting decrease in organic matter, and changes in the water regimes of the whole soil due to artificial drainage.

In 1940, Pearson, Spry, and Pierre published a paper entitled "The Vertical Distribution of Total and Dilute Acid-soluble Phosphorus in Twelve Iowa Soil Profiles". Since that time there has been an interest in understanding and predicting the phosphorus regimes of Iowa soils. The paper cited and other subsequent research formed the basis for the refinement of soil test recommendations that recognize low and high subsoil P categories. This distinction results in the range of soil test categories being modified to acknowledge the difference in available subsoil P. For example, the very low soil test category for P for corn production is 0-8 ppm for soils with low subsoil P but 0-5 for soils with high subsoil P. The differences in subsoil P are directly related to the composition of the P compounds in soils which in turn is related to the factors of soil formation. Therefore, it is important to understand the transformations and dynamics of P that occur in soil ecosystems.

Phosphorus Forms in Soil

Terminology used to describe various forms of P in the soil is diverse but most researchers use terminology related to the extractant used. Smeck (1985) used the terms soluble, labile, primary minerals, secondary minerals, organic and occluded to describe P forms. Soluble P is extractable with water or a dilute salt. Labile P is isotopically exchangeable or anion resin extractable phosphorus which is in equilibrium with P in the soil solution. Primary minerals are apatites which are acid-extractable. Secondary P minerals include minerals with P chemisorbed to their surfaces (commonly Fe and Al oxides and carbonates) as well as minerals formed by low temperature crystallation which contain P as a structural component. Secondary P minerals can be viewed as dictating long-term sluggish movement toward equilibria. Organic P is that P associated with organic matter. Occluded P is used to describe P that is physically encapsulated by minerals which have no P in their structure.

Transformations

A version of the P cycle is shown in Figure 1. The initial source of all P in soils is the primary minerals present in the parent material. Apatite is the most common primary mineral to serve as a source for P. Its solubility is increased under acid conditions and soluble P is released. The soluble P may be leached, taken up by plants or microorganisms, enter the labile pool, or be transformed into secondary minerals. Soil properties which determine the anion exchange capacity control the size of the potential labile P pool. However, the actual quantity of the labile P is related to the solubility product and dissolution of kinetics of secondary P minerals. Some secondary P forms (dicalcium phosphate dihydrate or octo-calcium phosphate rapidly equilibrate with labile and soluble P but other such as hydroxyapatite equilibrate so slowly that equilibrium is seldom attained (Murrman and Peech, 1969). While it is generally thought that P is relatively immobile in soils, this is not true over the longer term. Phosphorus profiles are interpreted in term of eluvial and illuvial horizons (Runge and Riecken, 1966; Fenton et al., 1967)

Soil Test Phosphorus (STP)

Soil test data reported in this paper unless otherwise specified were determined by the Bray 1 method. This method uses a weakly acid extractant and solubilized P in two ways: 1) the acid extractant (pH 3) solubilizes mostly acid-soluble Ca-phosphates and some Al- and Fe-phosphates that become soluble at low pH values and 2) the addition of NH_4F ions complexes the Fe and Al in the soil solution. Other methods will solubilize different amounts of P. However, the importance of any method is the ability to extract a representative portion of the P available to the plant that in turn can be used to predict the availability of soil P to the plant under a variety of conditions. Figure 2 shows the relationship between pH and phosphorus solubility in the soil. The dashed line shows the upper limit of available P in solution and illustrates the reason that for soils with 2:1 type clay minerals the optimum pH for P availability is in the pH range of 6.5 to 7.0. The dominant P form at this pH is $H_2PO_4^-$ and HPO_4^{--}.

Birchett (1974) studied the relationship of the Bray , Olsen, and Resin extractable P for soils of southwest Iowa. Data for three southwestern Iowa soils and a comparison with a Tama soil from eastern Iowa are shown in Figure 3. In all the soils studied, less P was extracted by the Olsen extractant than by the Bray or Resin extractant. However, the slopes of the STP depth-distribution curves are similar. Two major exceptions were the Rathbun and Weller profiles in which certain horizons had greater amounts of extractable P by the Resin method than by the Bray. Similar but smaller differences were reported for the Kniffin profile. These difference were attributed to the possibility that the Resin method prevented the readsorption of dissolved P by the clay surfaces. The ratio of the amount of STP extracted varied with horizon. The Olsen method extracted relatively more P with increasing depth in the profiles suggesting that this method extracts a larger portion of the Ca-P. The Olsen method had a higher correlation with plant-available P in the C horizon than the Bray method. For the subsoils, the simple correlations between Bray P and Olson P decreased with horizon depth and was associated with the decreasing correlations with depth with slight increases in average soil pH.

As the soil depth and soil pH increased, the ratio of Ca-phosphates to the Fe-and Al-phosphates increased, the relative effectiveness of the Bray to the Olsen method decreased. Addition of the soil pH variable increased the correlation between the two but horizon depth was not included in the regression and may also have been a factor. Miller (1974) studied Tama profiles in eastern Iowa on different landscape positions. He compared the Bray 1 and Bray 2 extraction methods. The Bray 2 method uses 1N HCL as compared to .025 N HCL for the Bray 1. He reported that the Bray 2 method extracted 1.4 to 1.7 times more STP than the Bray 1 method in the sola of the well and somewhat poorly soils studied. Below forty inches, the Bray 2 method extracted 2.4 to 2.7 times more STP than Bray 1. When pH values increased to near neutral the Bray 1 decreased by 50% and the Bray 2 STP increased by several hundred percent. Athe increase in Ca-P with depth is severall times greater in the near neutral range than in acidic soil environments.

Effect of Profile differentiation on STP

The soil forming factors important in profile differentiation are climate and time. Climatic factors of temperature and precipitation are especially important in chemical reactions in the soil. Precipitation provides the soil water necessary for chemical reactions and leaching. Temperature is an important factor in the speed of reactions. Time is an important factor in the stage of weathering, usually described in terms of youth, maturity and old age. Birchett described the depth-distribution of STP for soils formed in loess parent material under prairie vegetation. Three zones, designated as zones 1, 2, and 3 are shown in Figure 4 for a Marshall soil with STP values determined by the Bray 1 method. He also studied transition and forested soils from southern Iowa. Soils formed under forest vegetation have the same general depth curve for STP but have greater amounts of STP. Zone 1 was described as the surface or A1 horizon for virgin soils or the Ap horizon for cultivated soils. It is the part of the soil where cropping, return of plant residues, and the additional of fertilizers and manure can cause large variation in STP. However, there are also other factors that affect P availability to plants. Availability is a function not only of the amount in solution but also the amount of water present in the soil and the distance the P must move to reach the root.

Zone 2 is the part of the STP depth curve with the lowest amount of P. It is generally in those horizons immediately beneath the Ap or A1 horizons and includes either parts or all of the E, A2.., and upper part of the B horizon. This depth is often between 6 and 24 inches for most of the profiles studied by Birchett.

Below the minimum STP levels, the amount of STP increases to a zone of maximum solubility that is usually in the lower B horizon or the upper B horizon. In many of the profiles studied, this zone was at a depth of 36 to 48 inches. If free

carbonates were encountered, above this depth very low levels of STP were present. In these cases, the maximum solubility occurred in less alkaline or more acid horizons closer to the soil surface.

Ida, Monona, Marshall, and Sharpsburg comprise a developmental sequence of loess-derived soils formed under prairie vegetation. Ida soils have free carbonates throughout their profile. Ida soils are low in available P. Birchett reported that for the Monona soils studied there was a wide range of Bray-extractable P that were apparently related to the degree of weathering. The Monona profiles with high pH and shallower depth to carbonates had low amounts of extractable P and were close to the Ida soils in their characteristics. As the soil properties of Monona came closer to Marshall soils, extractable P increased. These relationships result in range of extractable P in Monona soils. The same trends were reported for Marshall soils (Figure 5A). Those profiles sampled in the Monona-Marshall transitional area had P distributions similar to the Monona profiles while those in the Marshall-Sharpsburg transition area had P distributions similar to those in the modal Sharpsburg area. The differences in amounts of extractable P were apparently related to soil pH. Those profiles with high amounts of extractable P had pH values ranging from 5.67-6.06 in the 24 to 48 inch horizons while those profiles with lower amounts of extractable P had pH values ranging from 6.31 to 6.87. It appeared that the lower pH values increased the solubility of Ca-phosphates in these soils. The largest amount of extractable P was in the C1 horizon, at the base of the solum, where weathering had removed the free carbonates and the pH was slightly below neutrality.

Soil Test P and Vegetation

The early work of Pearson et al., 1940 demonstrated the effect of different native vegetation on the STP content of soils. However, while native vegetation may be the most obvious variable present, soil genesis theory uses the term organisms which is a more holistic approach and sets soil as a part of the ecosystem. STP is responsive to the total ecosystem and it is difficult to separate the variables but the soil, as influenced by the dominant vegetative type and associated environment, is the component tied most closely to the STP. Within a biosequence (a sequence of soil alike in all soil forming factors except vegetation) the forested member has the highest content of STP, the transitional member (both grass and forest) is intermediate and the prairie soil has the least. This comparison is true in relative amounts as shown in Figure 5B. However, note that the STP content of Tama, a loess-derived prairie soil, is higher than that of Kniffin, a loess-derived forested soil. However, the Kniffin soils are more highly weathered than the Tama soils.

Kazemi (1983) summarized soil test data from 251 profiles located in the eastern part of Iowa. Counties included were Bremer, Howard Fayette, Linn, Muscatine, and Keokuk. The major objective of this study was to study the effect of soil property differences, including native vegetation, on the amount and depth-distribution of STP. Multiple regression techniques were used to develop prediction equations for STP. The native vegetation had a dominant effect on STP and decreased from forest to prairie (Figure 6 & 7). Eroded soils had lower subsoil STP levels than uneroded soils. The STP decreased from well to poorly drained soils(Figure 8). Runge and Riecken (1966) also reported higher amounts of available P in somewhat poor and moderately well drained soils as compared to poorly drained soils. This trend was related to higher pH values in the poorly drained soils in both studies. Kazemi also found that loess parent material had higher subsoil STP than any other group of parent materials, till parent material had the lowest STP and STP values decreased linearly from convex to concave slopes.

Soil Test P and Parent Material

In general, soil formed in loess have higher contents of STP when all other soil forming factors are constant. The differences between Tama (loess-derived), Kenyon (till-derived) and Clarion (till-derived) are shown in Figure 9. Figure 10 presents a summary of the analyses by Kazemi (1983) relating STP depth distribution to major parent materials in Iowa. Eolian deposits (excluding loess) were lowest in STP. Loess was highest. Alluvium, till, and loess over till were intermediate in STP content.

Total Phosphorus

Major environmental concern for soil phosphorus involve phosphorus leaving a soil surface in the form of dissolved P in

runoff or with the soil particle in erosional processes. Therefore, a knowledge of the total phosphorus content of soils and the depth distribution of total phosphorus in different soils are important parameters to understand. While it is generally thought that P is relatively immobile in soils, this is not true over the longer term. Total phosphorus profiles, such as the ones shown in Figure 11 , are interpreted in term of eluvial and illuvial horizons. Two deep profiles, one beneath Marshall and the other beneath Tama show the depth trends expected in well drained soils formed in thick loess, one in western Iowa (Potawattamie County) and the other in eastern Iowa (Tama County).

Vegetation (Biotic Factor)

Biosequence effects on the genesis and resulting differences in soil phosphorus have long been recognized (Pearson et al., 1940; Fenton et al., 1967; Mausbach, 1969; Tembhare, 1973; Collins, 1977; Miller, 1974. Fenton et al., 1967 arrayed soil profile data by biosequences to test the effect of native vegetation on the phosphorus characteristics of soils. Total phosphorus was high in the surface horizon, decreases to a minimum and then increased with depth within all members of the biosequences. The general trend of the distribution is similar whether the parent material is loess or glacial till. The depth distributions of the well and moderately drained loess-derived soils are shown in Figure 12 and the well drained till-derived soils are shown in Figure 13. Depth to the TP minimum is most shallow in the forested member of the biosequence (Table 1). The TP minimum within a biosequence is always less in the transitional or forested member as compared to the prairie member.

Within a biosequence the forested soil also has the lowest content of less than 2 micron clay in the minimum TP horizon. The TP minima in the prairie soil profiles are more closely associated with the maximum clay content within the profile. This trend is illustrated by the data in Table 2. The average clay content in the horizon of minimum TP decreases from 37.2% for the prairie soils to 20.1% for the forest soils. The range in the mean maximum clay within the profiles varies within a narrow range of 38 to 40.6%. The trend is shown in Table 2. In the forested soils and the transitional Grundy soils the TP minima coincides with the part of the zone described as the E horizon. In all other soils, except for the transitional Grundy soil, the TP minimum is in the B horizon and it is most closely associated with the zone of maximum clay in the prairie soils (Table 2). The data relating minimum TP values to layer of maximum clay content in prairie soils is in agreement with the observations of Runge and Riecken (1966). In the transition and forested members the minimum TP value are more closely associated with the upper B or E horizon and not the zone of maximum clay.

Figure 12 shows the depth distribution of total P for a number of well to moderately well drained loess-derived biosequence. There are differences in the depth distributions related to the native vegetation. Forested soils have the greatest amount of total P to a depth of 40 inches as shown in Table 1. In general, for well drained soils, where we expect the net vector of water movement to be downward, the P distributions are more predictable. Figure 14 shows the loess-derived somewhat poorly drained Muscatine and Mahaske biosequences and Figure 15 shows the poorly drained landscape associates of these soils. Figure 13 shows the total P distribution in two till-derived biosequences. The Clarion and Kenyon biosequence members are well-drained and have similar depth distributions of total P as the well-drained loess-derived soils but lower amounts. The till-derived somewhat poorly drained Nicollet and the poorly drained Webster biosequence are also shown in Figure 13. These soils have higher fluctuating water tables and thus the depth distribution of total P in these soils is less predicable that for the better drained soils.

As soil horizon differentiation increases, the P minerals change in form and distribution. With respect to phosphorus, native vegetation differences are related to forms of phosphorus. Mausbach (1969) reported that the levels of Ca-phosphates decreased and the Fe and Al-phosphates increased progressively from the prairie soils to the transitions and to the forested soils (Figure 16). This increase in Fe and Al phosphates was associated with decreasing pH from the prairie to the forest soils. This relationship is illustrated in Figure 17 which shows the relationship between pH and the ratio of Fe-P + Al-P divided by Ca-P for a number of Iowa soils. Hsu and Jackson (1960) found that Fe and Al-phosphates are stable at pH values lower than the pH values at which Ca-phosphates are stable. The lower pH under forest vegetation contributes to increased weathering rates. Smeck and Runge (1971) showed increasing aluminum, iron and reductant soluble P and decreasing calcium P along a traverse from a Haplaquoll to an Albaqualf at the end of the transect. They also found a progressive increase in STP along the same traverse. P availability increased as horizon differentiation increased.

Westin and Buntley (1966a, 1967) reported that the cooler drier Borolls had less Fe-P and reductant P and more Ca-P than the Ustolls in South Dakota.

Parent Material

Loess generally has higher contents of TP than till (see Figures 12 & 13). Pearson et al. 1940, reported that the glacial till they studied contained about 300 ppm of TP while the loess averaged about 700 ppm. These difference related to parent material have also been reported in subsequent research in Iowa. However, the actual difference in the amount of total of phosphorus present is less if bulk density is considered. An acre foot of till (assuming a bulk density of 1.5) and using the 300 ppm content has 122,316 pounds of P while an acre foot of loess has 247,350 pounds. Corrected on this basis the loess has approximately twice as much TP rather than 2.3 when expressed in ppm. However, the TP content of the loess ranges from the value cited above to lower values where the loess sections have been weathered. For example, Seymour soils in southeastern Iowa formed in loess but the TP content of the least altered loess is 540 ppm while in western Iowa beneath the Marshall soil TP contents of 850 ppm are present. TP content of alluvium has a wide range. TP contents are low in more weathered alluvium and highest in calcareous alluvium.

Time and Topography

The plot shown in Figure 18 shows the effect of time and topography on TP. Clarinda is a paleosol derived from pre-Illinoian till. Note the low content of TP in this soil. The low TP content is attributed to the advanced stage of weathering of this soil The Sperry soil is a loess-derived very poorly drained soil in eastern Iowa. It occurs in closed depressions and has the highest TP contents that I found in the Iowa data. Smeck, 1973; Walker and Syers, 1976; Smeck and Runge, 1971 showed that phosphorus is translocated within the soil profile and landscape within a pedologic time-frame. Smeck (1985) reported that of the soils studied in Illinois, in each toposequence the TP content was highest in soils on the low end of the hydrologic gradient. The content of TP in Sperry supports that interpretation. Theoretical changes in P over time are shown in Figure 19. Note that eventually all the primary P minerals will weather. Walker and Syers (1976) suggested that for the soil conditions they studied, this process would take about 22,000 years. Occluded P continues to increase at the expense of secondary P until eventually only occluded P and organic P remain.

Organic P

Kosse (1966) studied organic carbon/organic phosphorus ratios in selected Iowa soils. Values for surface horizons of the poorly drained soils studied ranged from 90 to 152 and were markedly higher than for the somewhat poorly, moderately well and well drained soils. It has been well established that the driving force for conversion of primary to secondary and occluded forms is decreasing pH due to weathering and leaching of the soil. However, the driving force for organic P has not been as well documented. Early work suggested a direct relationship between organic matter and organic P content of a soil. However, Smeck and Runge (1972) determined that organic matter production may be limited by factors other than P availability. Low levels of organic matter content occur in some soils with high levels of available P. Organic P is more stable at low pH rather than high pH. Liming tends to allow breakdown and mineralization of org P. Both N and org P decline with cultivation. Organic P is held by covalent bonds and does not ionize. Decomposition breaks down O2 bonds and the P can mineralize. The adsorption of P is stronger than that for cations. Figure 19 shows an idealized diagram of soil development related to organic P and organic C.

Summary-Soil Test Phosphorus and Total Phosphorus

Figure 20 shows a plot of TP and STP for a Tama soil in Iowa. As might be expected, there is no direct relationship between TP and STP. However, TP is a key element in soil genesis. As soils develop, the TP undergoes changes that are related to the weathering environment. We expect the amount and forms of TP to change with soil-forming processes. It was demonstrated that the driving force for conversion of primary to secondary and occluded forms is decreasing pH due to weathering and leaching of the soil. STP was shown to be highest in soils formed under forest vegetation and this in large part is due to the forms of phosphorus which in turn is related to pH and the weathering process. Forest soils are more acid and the weathering of clay minerals release Fe and Al which in turn react with the phosphorus. The amount of STP extracted for a given soil is related to the combination of P forms and pH (Figure 2).

P and Environmental Problems

As discussed by Voss and Griffith, agriculture has been designated as the primary source of phosphorus entering inland streams, lakes, and water impoundments. Phosphorus leaves agricultural fields as dissolved phosphorus and particulate phosphorus attached to soil sediment. Crop production cultural practices were cited as major factors in the concentration and amount of P in the runoff. Thus far, I have used primarily soil series names in this paper. However, on a landscape basis, the soil unit that provides the most information is the soil map unit, a combination of the soil series and phases including surface texture, erosion phase and slope class. It is at this level that nutrient management plans should be based. Soil map units within one soil series exhibit wide ranges in organic matter content, clay content, slope gradient, length, and configuration all of which are factors that contribute to the amount of dissolved and particulate phosphorus moved in runoff. For example most of the well and moderately well drained soil series have several slope and erosion phases. The differences described in the soil series description state the following: " The thickness of the A horizon, depth to subhorizon highest in clay, maximum percent clay, thickness of Bt horizon, depth to carbonates, depth to mottling and solum thickness usually decrease as gradient increases on convex slopes". These factors indicate that each soil map unit has a distinct set of characteristics that will interact with the type of cultural practices used for any field. These are all important properties that should be a part of any soil management decision-making process.

Soil Survey

Soil survey involves the mapping, classification, correlation, and interpretation of soils. The first soil survey in Iowa was in the Dubuque County area but did not include the entire county. The field work was done in 1902 and the report was published in 1903. Since that time, most Iowa counties have had at least two soil surveys completed and some have had three. The basic factors of soil formation have not changed but the use of the soils for intensive agriculture has resulted in changes in some soil properties, especially of the surface horizons. However, generally factors other than soil differences have been responsible for multiple soil surveys over one area. Over time, our concept of soil has changed. Early soil scientists with a background in geology considered the soil to be primarily that part of the earth's surface that had been darkened by the addition of organic matter., Our concept of soil has evolved so that soil now is considered a natural body made up of several horizons or layers that are genetically related to the soil forming factors under which the soil has developed. Total analyses of soils for phosphorus and potassium was a common practice during the early 1900's. Later, it was learned that it was not the total amount of a nutrient that was important for plant growth but the amount that was available to the plant. Other major factors in resurveys were the scale and the base map used.

The early soil maps were generally made at a scale of 1 inch per mile on a plane-table base map. In the late 1930's the use of aerial photographs as base maps for soil survey was implemented. Most of the surveys were made at a scale of 4 inches per mile and most of the modern surveys we have in Iowa were made at that scale. Beginning in the 1990's, orthophotographs were used as base maps and the field mapping is presently being done at a scale of 1:12,000 or 5.28 inches per mile.

Availability of Soil Information

Soil surveys are available for all Iowa counties in published reports and presently 95 of the 99 counties also have the same information available in digital format. Many digital soil maps of Iowa are available on the internet at http://www.ia.nrcs.usda.gov/

To access the soil information select-Soils, Soils Information, and Digital Soil Survey Data From Iowa Cooperative Soil Survey on successive screens. Data bases giving soil properties and interpretations are available at the same site. The Iowa State University Extension home page also contains soil information as well as a link to the digital soil maps and databases. The home page address is:
http://extension.agron.iastate.edu/soils/soilsurv.html
Descriptions for all soil series in the U.S. are located at: http://www.statlab.iastate.edu/cgi-bin/osd/osdname.cgi
For those who do not have access to the internet, the digital soil information and associated data bases are available on CD-ROM or diskettes. The digital soil information is available in several different formats and is suitable for use in most Geographic Information Systems (GIS). For those users not interested in using a GIS the digital information may be used with the ISOIL program which is our software package for handling soil maps and data. Contact me at the above address if you have questions on the availability of soil information in Iowa.

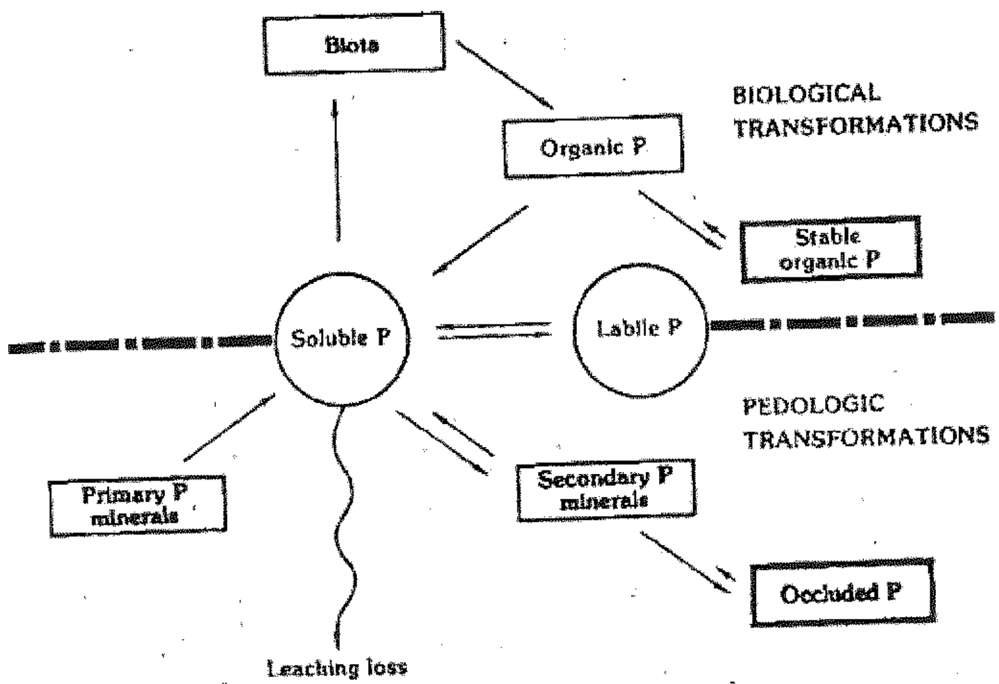


Figure 1. Phosphorus transformations in natural soil ecosystems. From Smeck (1985)

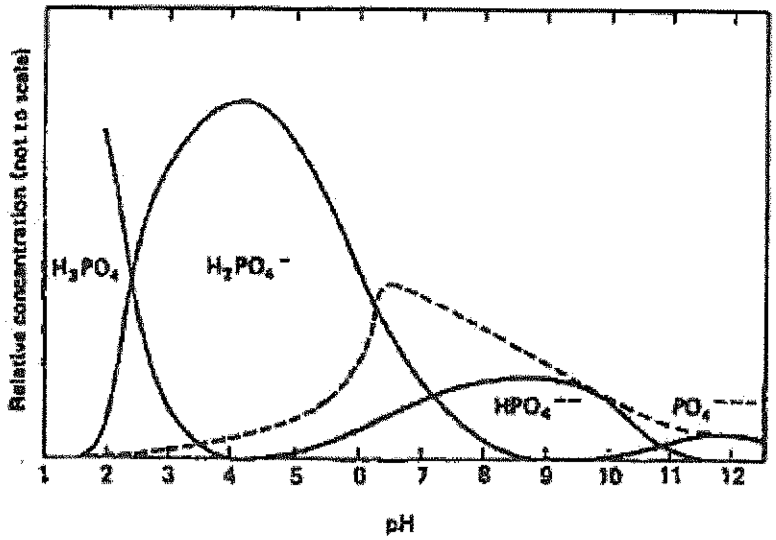


Figure 2. Relative proportion of phosphate ions in solution at different pH levels in a Ca-H_3PO_4 system. From Troesh, 1993.

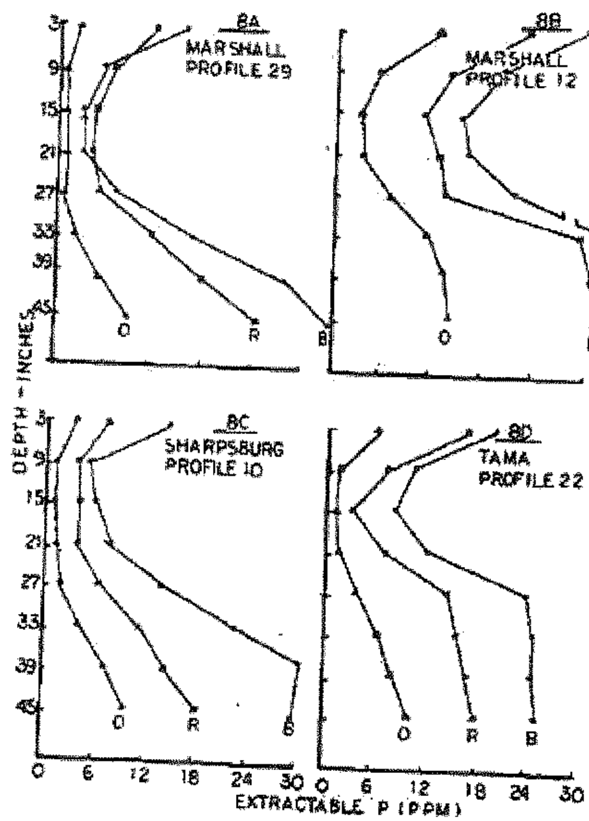


Figure 3. Comparison of three phosphorus extraction methods. From Birchett, 1974.

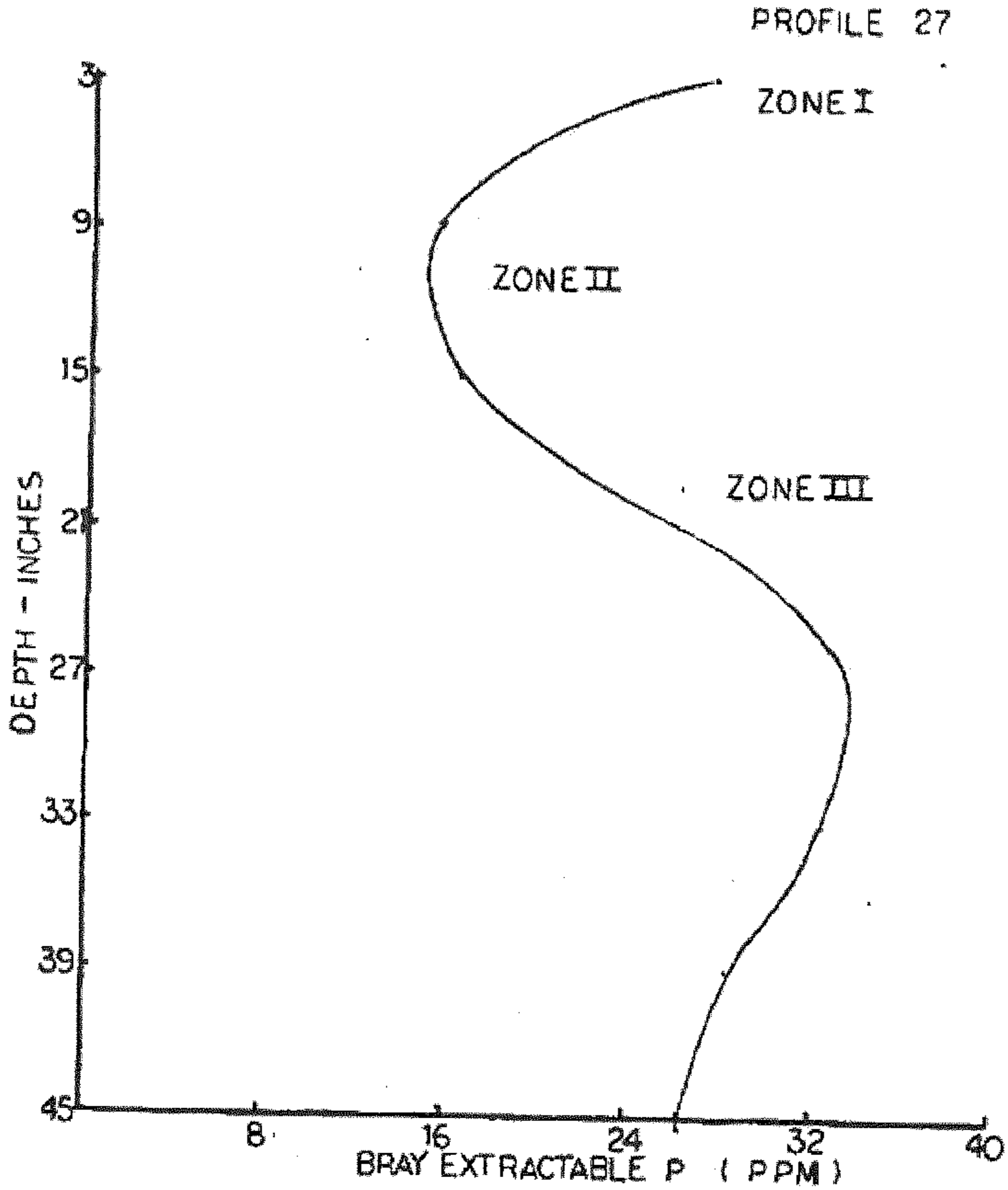


Figure 4. Zones in STP depth-distribution for deep loess. From Birchett, 1974.

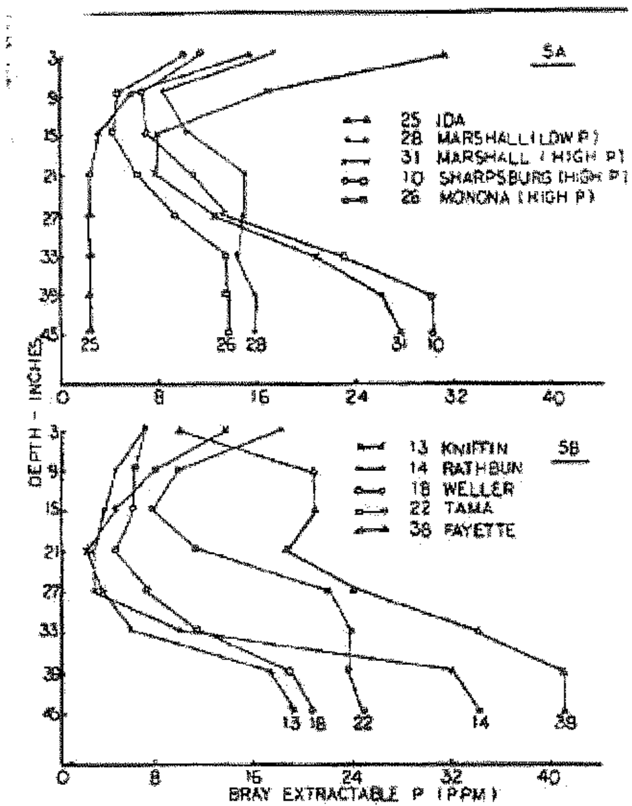


Figure 5. STP depth distribution for selected loess-derived soils. From Birchett, 1974.

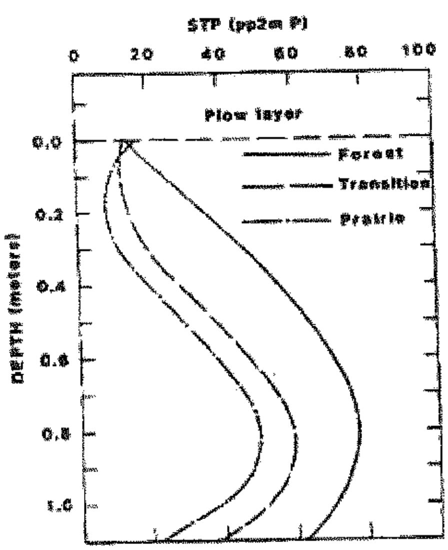


Figure 6. Predicted STP depth distribution for loess-derived biosequences. From Kazemi, 1983.

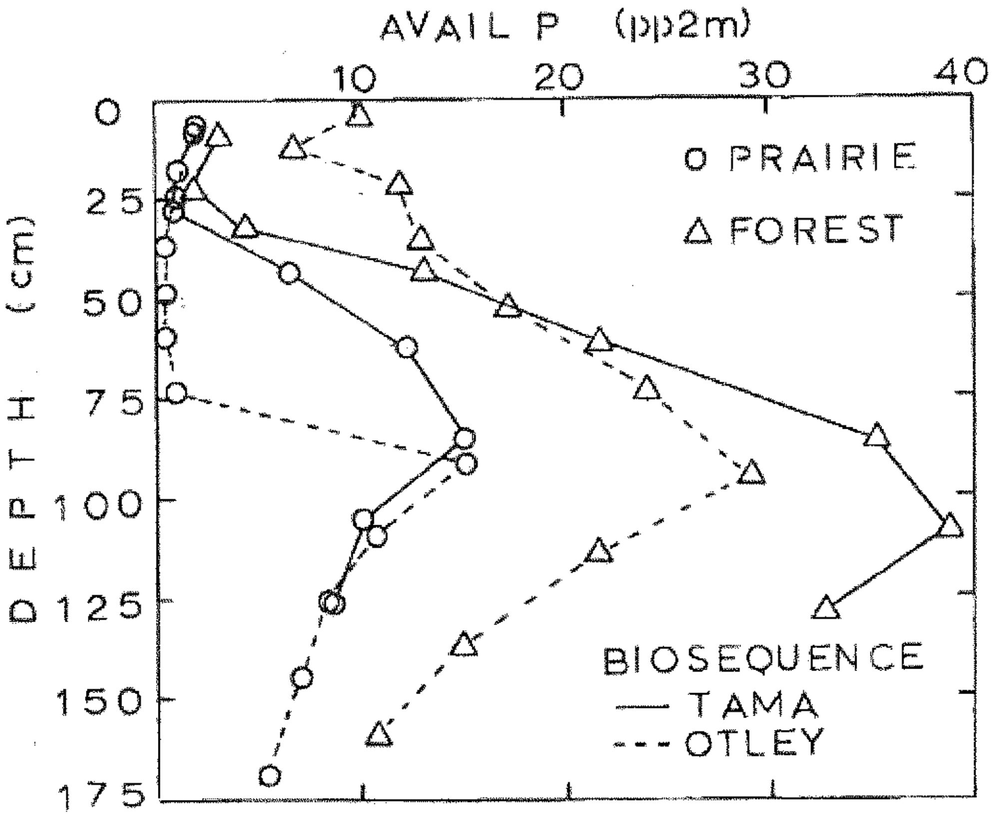


Figure 7. STP depth distribution for Tama and Otley biosequences.

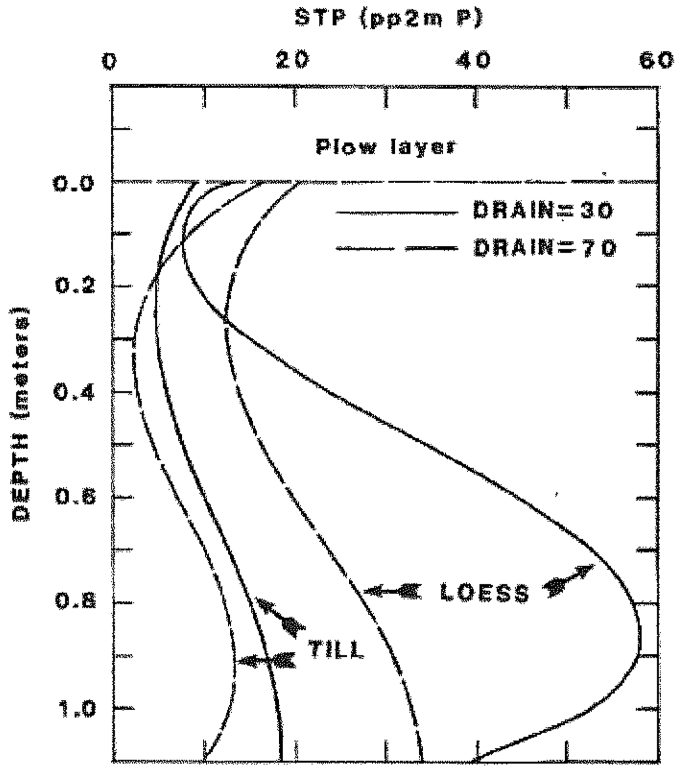
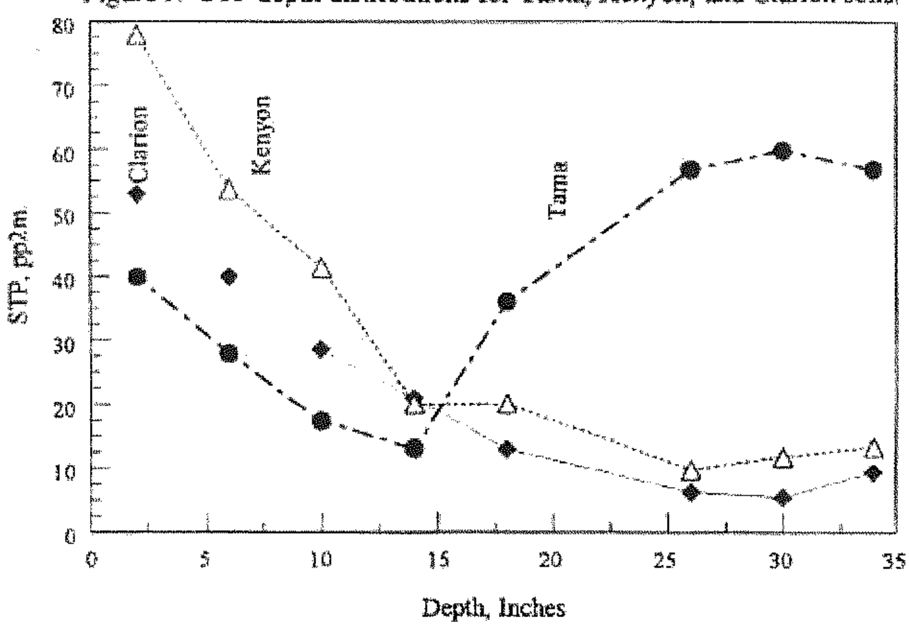


Figure 8. Predicted STP depth distribution for well drained (30) and poorly (70) drained loess and till-derived soils. From Kazemi, 1983.

Figure 9. STP depth distributions for Tama, Kenyon, and Clarion soils.



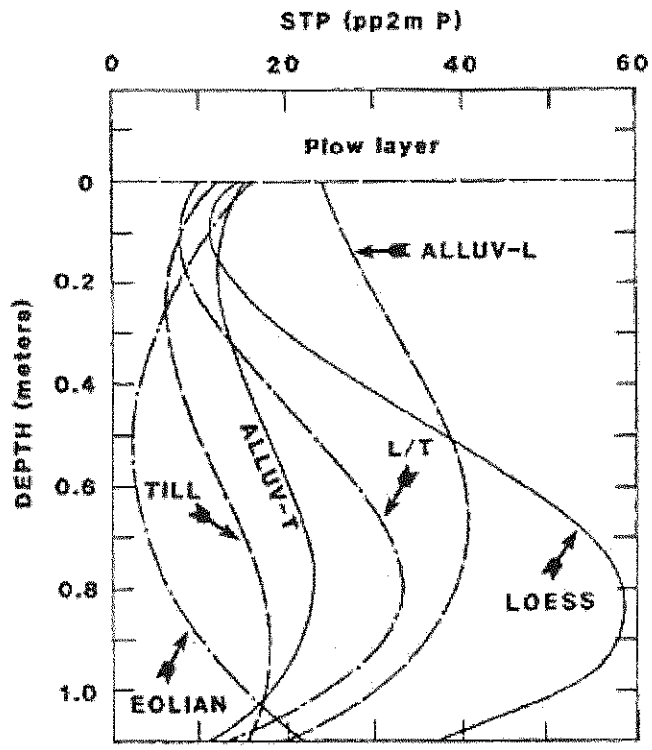
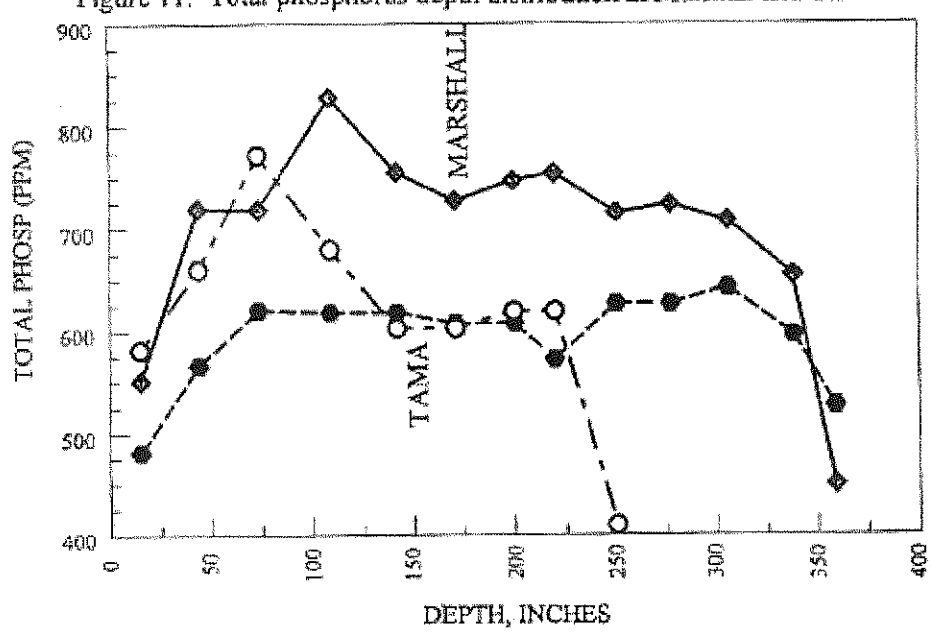


Figure 10. Predicted STP depth distribution for Iowa soil parent materials. From Kazemi, 1983.

Figure 11. Total phosphorus depth distribution in Marshall and Tama soils.



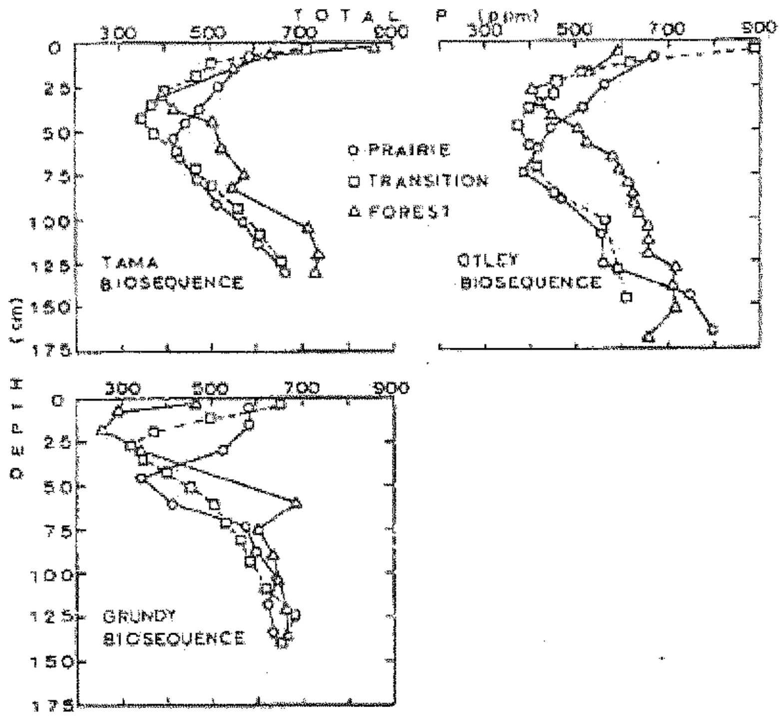


Figure 12. Depth distribution of TP for loess-derived moderately well and well drained soils.

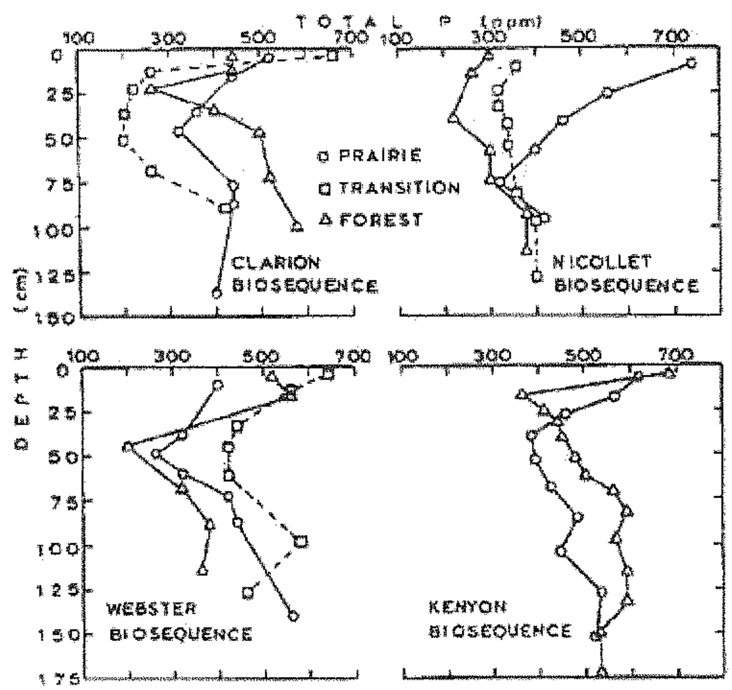


Figure 13. Depth distribution of TP for till-derived moderately well, well drained soils, somewhat poorly and poorly drained soils.

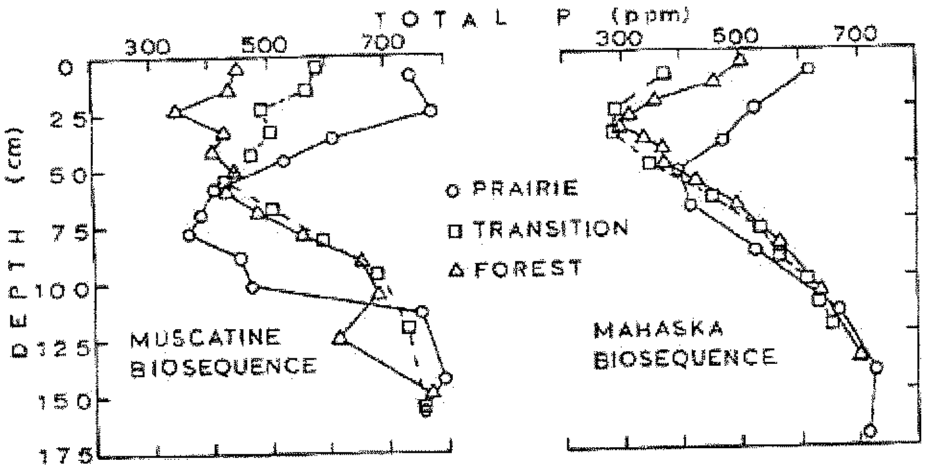


Figure 14. Depth distribution of TP for loess-derived somewhat poorly drained soils.

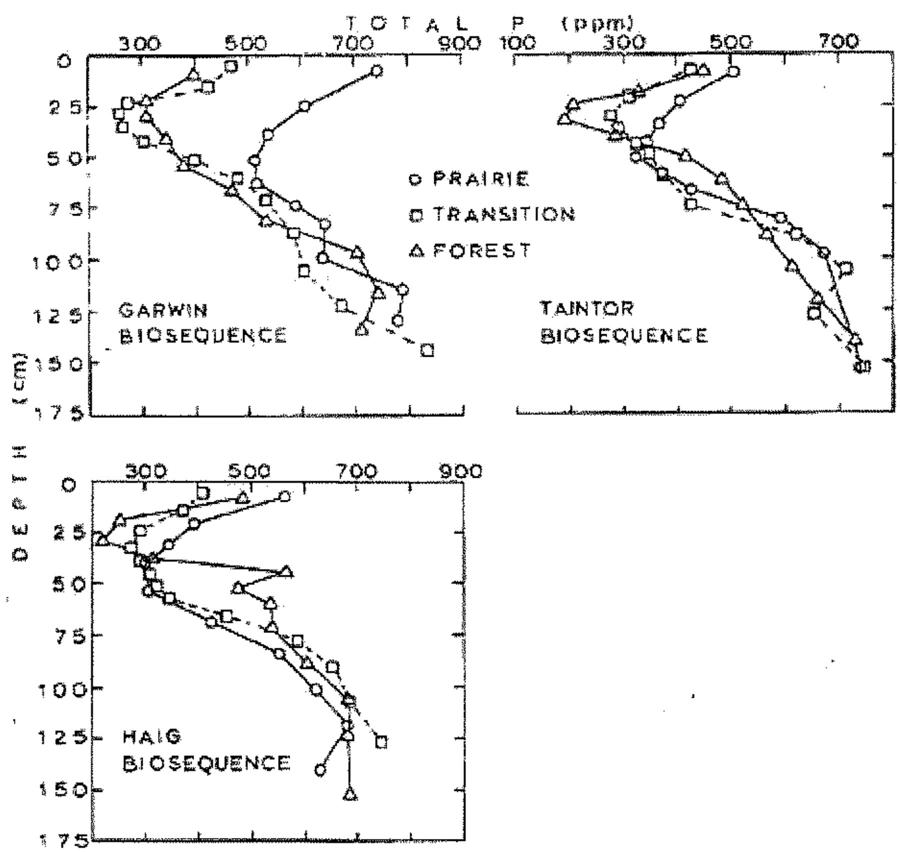


Figure 15. Depth distribution of TP for loess-derived poorly drained soils.

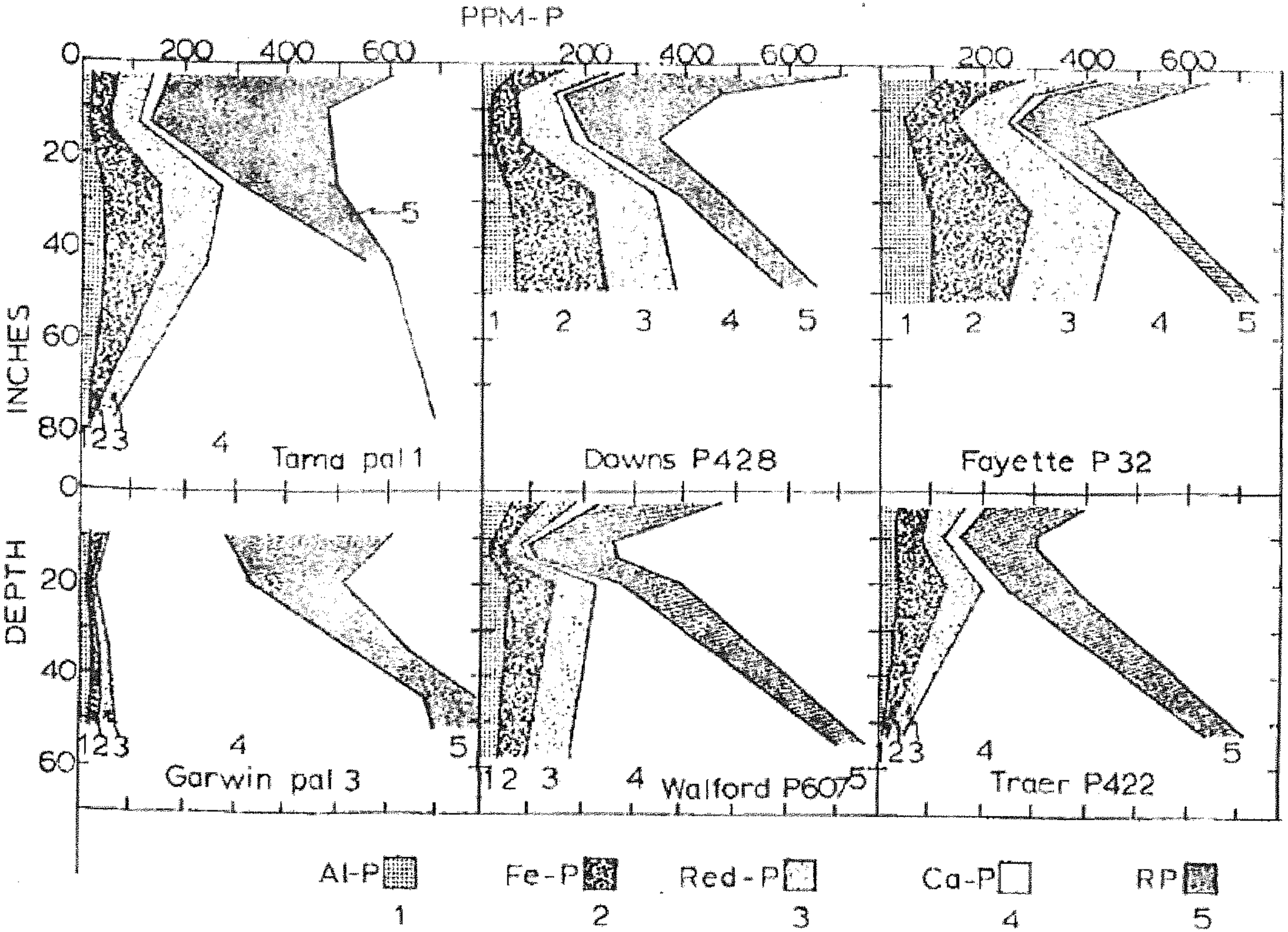


Figure 16. Phosphorus fractions in the Tama and Garwin biosequences. From Mausbach, 1969.

Figure 17. Phosphorus fraction ratios and pH for selected Iowa soils.

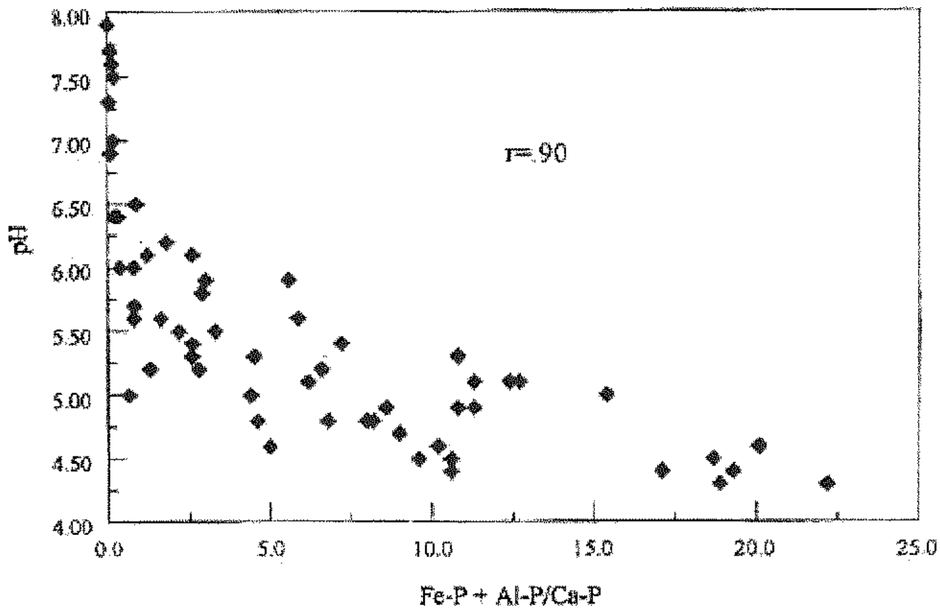
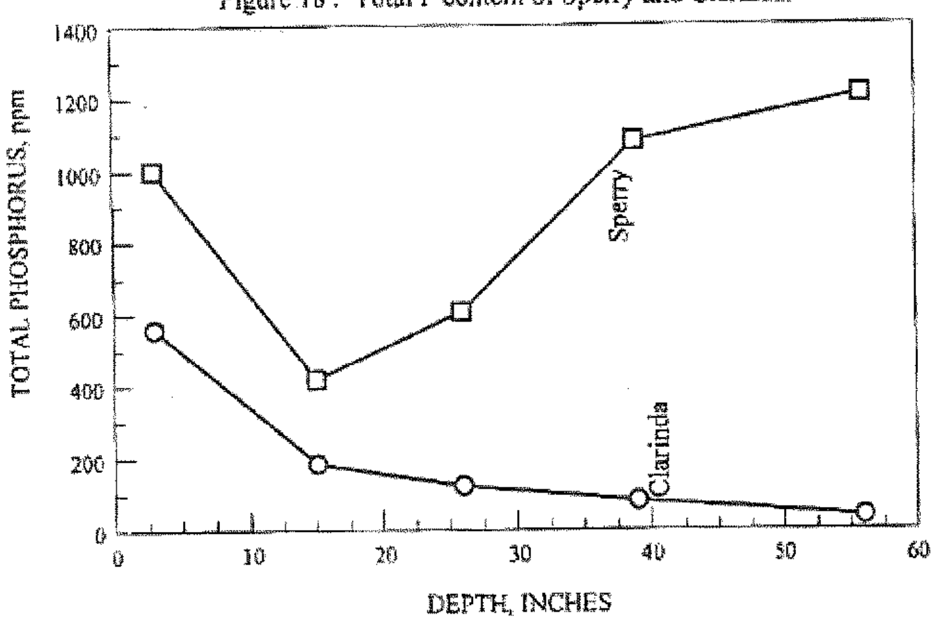


Figure 18. Total P content of Sperry and Clarinda.



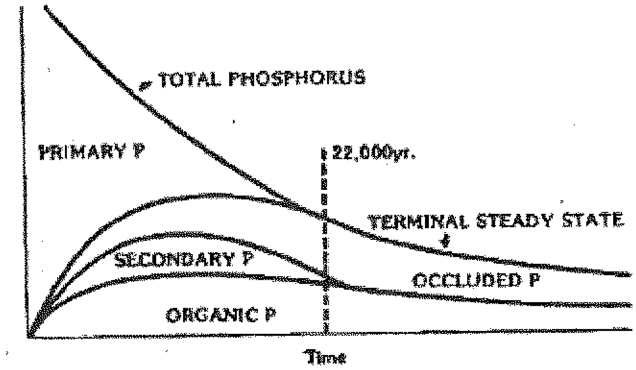


Figure 19. Changes in forms and amount of phosphorus with time. From Walker and Syers, 1976.

Figure 20. Depth distribution of Total P and STP for Tama soil.

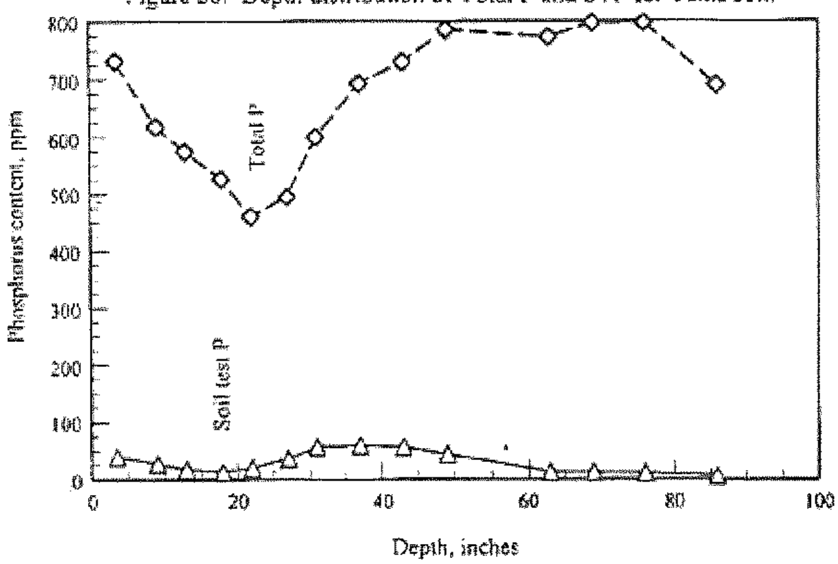


Table 1. AVERAGE TOTAL P PER 2.54 CM, TOTAL P MINIMUM, AND DEPTH TO TOTAL P MINIMUM

BIOSEQUENCE	$\overline{X}$ TOTAL P (TO 129.54 CM)*			TOTAL P MIN. (PPM)			DEPTH TO TOTAL P MIN. (CM)		
W TO MW DRAINED	P	T	F	P	T	F	P	T	F
TAMA	525	508	587	420	348	396	53.3	41.9	29.2
OTLEY	512	510	571	384	372	404	73.7	47.0	26.7
GRUNDY	543	524	587	345	320	258	44.5	26.7	17.8
SP DRAINED									
MUSCATINE	586	588	517	362	424	344	77.5	54.6	22.9
MAHASKA	536	464	501	399	285	299	53.3	35.6	33.0
P DRAINED									
GARWIN	640	488	508	513	260	310	57.2	27.9	25.4
TAINTOR	522	473	475	322	276	190	49.5	29.2	31.8
HAIG	488	492	518	300	276	220	40.6	33.0	29.2
MW DRAINED									
KENYON	474	-	525	384	-	366	39.4	-	16.5
CLARION	412*	302	471	320	200	260	45.7	41.9	22.9
SP DRAINED									
NICOLLET	486	352	294	320	320	220	74.9	29.2	39.4
P DRAINED"									
WEBSTER	375	504	388	260	420	200	48.3	53.3	44.5

*CLARION, NICOLLET, AND WEBSTER BIOSEQUENCE DATA BASED ON A TOTAL DEPTH OF 101.6 CM.

Table 2. DEPTH TO (TP) MIN. AND CLAY CONTENT AT THAT DEPTH

BIOSEQUENCE	DEPTH TO (TP) MIN. (CM)			< 2μ (%)		
M TO MW DRAINED	P	T	F	P	T	F
LOESS						
TAMA	53.3	41.9	29.2	31.0	31.1	20.5
OTLEY	73.7	47.0	26.7	36.2	32.8	22.1
GRUNDY	44.5	26.7	17.8	44.5	27.0	17.6
TILL						
KENYON	39.4	-	16.5	24.5	-	11.1
CLARION	45.7	41.9	22.9	25.8	27.5	24.2

BIOSEQUENCE	DEPTH TO (TP) MIN. (CM)			< 2μ (%)		
SP DRAINED	P	T	F	P	T	F
LOESS						
MUSCATINE	77.5	54.6	22.9	32.0	32.1	21.0
MAHASKA	53.3	35.6	33.0	39.6	28.2	28.3
TILL						
NICOLLET	74.9	29.2	39.4	33.1	27.1	20.0
P DRAINED						
LOESS						
GARWIN	57.2	27.9	25.4	35.2	24.8	28.3
TAINTOR	49.5	29.2	31.8	43.2	30.1	23.9
HAIG	40.6	33.0	29.2	37.7	23.9	17.7
TILL						
WEBSTER	48.3	53.3	44.5	34.0	34.0	35.4

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